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H. Author/Requestor
G. G. Kelty George Kelty
(Print and Sign)

Responsible Manager
J. V. Borghese J V Borghese
(Print and Sign)

I. Reviewers

	Yes	Print	Signature	Public Y/N (If N, complete
General Counsel	[x]	L. F. Willis	Leland F. Willis	Y / N
Office of External Affairs	[ ]			Y / N
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RESPONSIBLE CONTACTS

	Name	Phone Number
Author:	G. G. Kelty	373-4458
Interpretive Authority (IA)*:		

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DESIGNATED REVIEWERS

Name *(print)*	Organization
J. V. Borghese	Manager, GW Remedial Actions
J. D. Isaacs	Project Engineering Manager
J. A. Winterhalder	Environmental Compliance
L. C. Swanson	Geoscience Manager
V. G. Johnson	GW Remedial Actions

APPROVAL SIGNATURES

	Date Signed
Interpretive Authority*: Name: N/A	
Functional Manager:** Name: L. C. Swanson LC Swanson	4/29/04
President's Office Approval (for Policies and Management Directives only): Name: N/A	
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Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations

Prepared for the U.S. Department of Energy
Assistant Secretary for Environmental Management

United States
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Richland, Washington 99352

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Revision 0

Calendar Year 2003 Annual Summary Report for the 100-HR-3, 100-KR-4, and 100-NR-2 Operable Unit (OU) Pump & Treat Operations

G. G. Kelty
R. S. Edrington
V. G. Johnson
R. F. Raidl
K. Sathyanarayana

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Assistant Secretary for Environmental Management

United States
Department of Energy
P.O. Box 550
Richland, Washington 99352

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TERMS

CERCLA	*Comprehensive Environmental Response, Compensation, and Liability Act of 1980*
COC	contaminant of concern
CY	calendar year
DQO	data quality objective
EPA	U.S. Environmental Protection Agency
FH	Fluor Hanford, Inc.
FY	fiscal year
gpm	gallons per minute
HEIS	Hanford Environmental Information System
ISRM	In Situ Redox Manipulation
LWDF	Liquid Waste Disposal Facility
MCL	maximum contaminant level
NA	not available
OU	operable unit
QC	quality control
RAO	remedial action objective
RCBRA	River Corridor Baseline Risk Assessment
ROD	Record of Decision
RPD	relative percent difference
TPH	total petroleum hydrocarbons

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METRIC CONVERSION CHART

Into Metric Units			Out of Metric Units		
If You Know	*Multiply By*	*To Get*	*If You Know*	*Multiply By*	*To Get*
Length			**Length**		
inches	25.4	millimeters	millimeters	0.039	inches
inches	2.54	centimeters	centimeters	0.394	inches
feet	0.305	meters	meters	3.281	feet
yards	0.914	meters	meters	1.094	yards
miles	1.609	kilometers	kilometers	0.621	miles
Area			**Area**		
sq. inches	6.452	sq. centimeters	sq. centimeters	0.155	sq. inches
sq. feet	0.093	sq. meters	sq. meters	10.76	sq. feet
sq. yards	0.836	sq. meters	sq. meters	1.196	sq. yards
sq. miles	2.6	sq. kilometers	sq. kilometers	0.4	sq. miles
acres	0.405	hectares	hectares	2.47	acres
Mass (weight)			**Mass (weight)**		
ounces	28.35	grams	grams	0.035	ounces
pounds	0.454	kilograms	kilograms	2.205	pounds
ton	0.907	metric ton	metric ton	1.102	ton
Volume			**Volume**		
teaspoons	5	milliliters	milliliters	0.033	fluid ounces
tablespoons	15	milliliters	liters	2.1	pints
fluid ounces	30	milliliters	liters	1.057	quarts
cups	0.24	liters	liters	0.264	gallons
pints	0.47	liters	cubic meters	35.315	cubic feet
quarts	0.95	liters	cubic meters	1.308	cubic yards
gallons	3.8	liters			
cubic feet	0.028	cubic meters			
cubic yards	0.765	cubic meters			
Temperature			**Temperature**		
Fahrenheit	subtract 32, then multiply by 5/9	Celsius	Celsius	multiply by 9/5, then add 32	Fahrenheit
Radioactivity			**Radioactivity**		
picocuries	37	millibecquerel	millibecquerels	0.027	picocuries

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1.0 INTRODUCTION

Fluor Hanford, Inc. (FH) is currently operating five groundwater pump-and-treat systems across the Hanford Site. Three systems address groundwater in the 100 Areas: the 100-HR-3 Operable Unit (OU) system, which is treating hexavalent chromium at two sites (100-D and 100-H Areas); the 100-KR-4 OU system, which is also treating hexavalent chromium; and the 100-NR-2 OU system, which is treating strontium-90. Two pump-and-treat systems are remediating groundwater in the 200 West Area: the 200-UP-1 OU system, which is treating technetium-99, uranium, carbon tetrachloride, and nitrate; and the 200-ZP-1 OU system, which is treating carbon tetrachloride, chloroform, and trichloroethene.

This annual summary report discusses the groundwater remedial actions in the 100 Areas, including the interim remedial actions at the 100-HR-3, 100-KR-4, and 100-NR-2 OUs (Figure 1-1). A detailed description of the progress and performance of the In Situ Redox Manipulation (ISRM) barrier is reported separately.

The interim remedial actions chosen for the 100-HR-3 and 100-KR-4 OUs are pump-and-treat systems that use an ion-exchange medium for contaminant removal. The systems were designed to achieve three remedial action objectives (RAOs), as well as specific operational and aquifer performance criteria described in the interim remedial action Record of Decision (ROD), *Declaration of the Record of Decision for the 100-HR-3 and 100-KR-4 Operable Units at the Hanford Site (Interim Remedial Actions)* (EPA et al. 1996). The three RAOs are identified as follows:

- RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.
- RAO #2: Protect human health by preventing exposure to contaminants in the groundwater.
- RAO #3: Provide information that will lead to a final remedy.

The *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999) specifies the selected remedy and activities for the 100-NR-2 OU. Some of these remedial activities are ongoing actions, such as the pump-and-treat operation specified in the 1994 N-Springs action memorandum (Ecology and EPA 1994). The 100-NR-2 RAOs are summarized as follows:

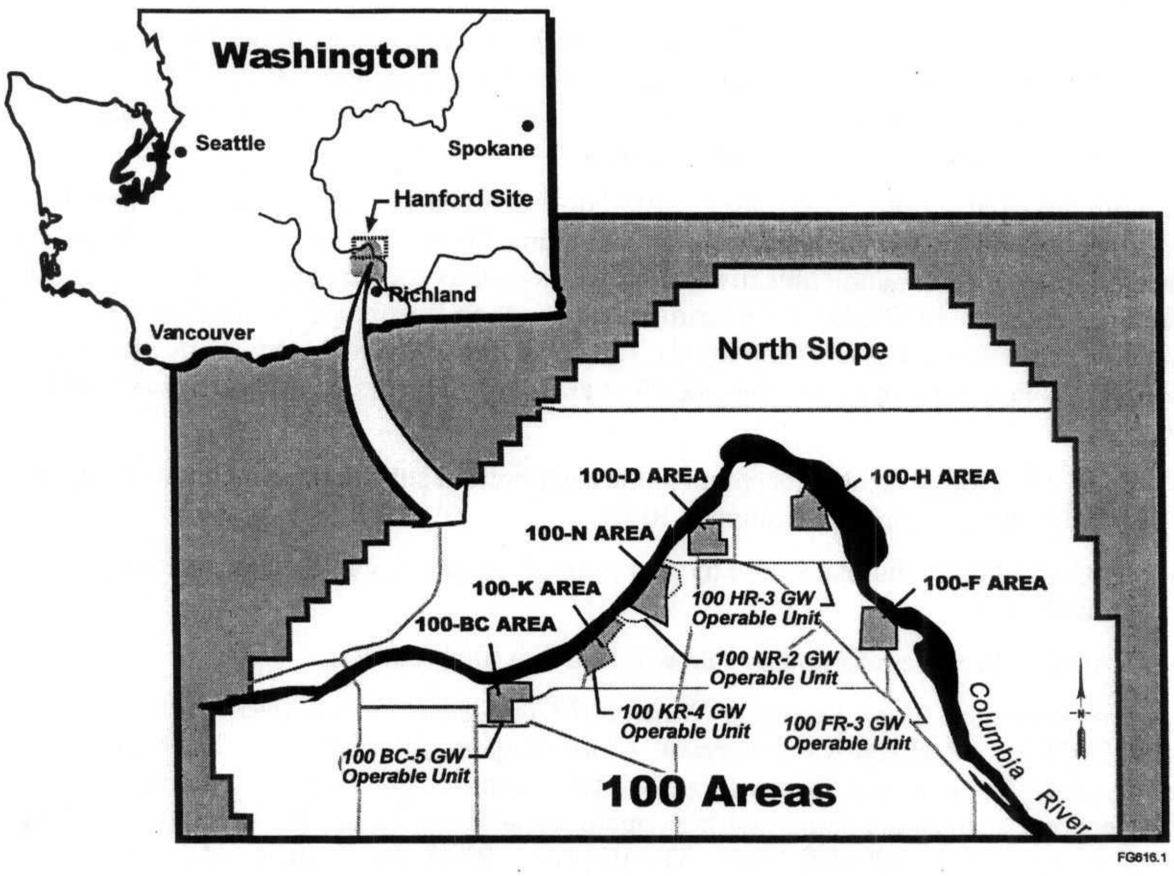
- RAO #1: Reduce strontium-90 contaminant flux from the groundwater to the Columbia River.
- RAO #2: Evaluate commercially available treatment options for strontium-90.
- RAO #3: Provide data necessary to set demonstrable strontium-90 cleanup standards.

This report discusses progress toward the RAOs in the respective conclusion section for each OU.

The report is organized into three major sections, each presenting the annual summary and performance evaluation for the three respective OUs. Section 2.0 discusses the 100-HR-3 OU, Section 3.0 discusses the 100-KR-4 OU, and Section 4.0 discusses the 100-NR-2 OU. An evaluation of costs is presented in Section 5.0, and the references cited in this report are included as Section 6.0.

This report provides a summary of major calendar year 2003 (CY03) activities, major trends, and significant differences between 2002 and 2003 for each OU in the main body of the report. An updated conceptual model discussion also has been included for each OU. Additional detailed text, tables, and/or figures providing historical information and trends are found in Appendices A through L.

Figure 1-1. Location of 100 Area Groundwater Operable Units.



2.0 100-HR-3 OPERABLE UNIT PUMP-AND-TREAT SYSTEM

The 100-HR-3 pump-and-treat facility is located in the north-central part of the Hanford Site along the Columbia River. The 100-HR-3 OU represents the groundwater underlying the source OUs that are associated with the 100-D and 100-H Reactor areas and the adjacent 600 Area (Figure 2-1). Groundwater extraction systems have been installed at the 100-D and 100-H Reactor areas, with a common treatment facility in a surplus building located near the H Reactor. The well locations for the 100-D Area are shown in Figure 2-2, and the 100-H Area well locations are shown in Figure 2-3. Treated groundwater is returned to the aquifer via injection wells, which are located in the 100-H Area, upgradient of the extraction well field. Appendix A provides a history of operations in the development of the 100-HR-3 pump-and-treat system.

This section provides the CY03 annual summary report for pump-and-treat operations in the 100-HR-3 OU, as required by the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL-96-84 Rev 0-A). Section 2.1 briefly summarizes activities within the OU potentially impacting activities associated with the pump-and-treat system. Section 2.2 summarizes the treatment system performance. Sections 2.3 and 2.4 review hydraulic conditions, provide a capture zone analysis through numerical modeling, and evaluate the contaminant concentrations for the 100-D and 100-H Areas. Section 2.5 discusses quality control (QC) results for groundwater samples. Section 2.6 updates key information related to the site conceptual models. Sections 2.7 and 2.8 provide conclusions and recommendations for the pump-and-treat system. Cost information is presented separately in Section 5.0.

2.1 SUMMARY OF ASSOCIATED ACTIVITIES

A summary of associated activities impacting the 100-HR-3 pump-and-treat system and associated tasks are presented below:

- Three new monitoring wells were constructed in the 100-D Area. Two wells (199-D-33 and 199-D5-34) were placed near the 182-D reservoir and a third well (199-D5-32) was placed northeast of the reservoir. The purpose of the new wells was to characterize water levels and contaminant concentrations that may be impacted by the reservoir and to enhance the current monitoring network.
- Leak detection activities were performed in association with an evaluation of the fire suppression system within the 100-D Area. Approximately 75% of the network was targeted for decommissioning in early CY04 as a result of this evaluation.
- The ISRM barrier was extended at the southwest portion of the treatment zone to a total length of 680 m (2,231 ft). The treatment activities included injection and extraction at wells 199-D4-80, 199-D4-81, 199-D4-82, 199-D3-03, and 199-D3-04. A detailed description of the progress and performance of the ISRM technology is presented in *Fiscal Year 2003 Annual Summary Report for In Situ REDOX Manipulation Operations* (DOE/RL-2004-06 [DOE-RL 2004, pending issuance]).
- Eight additional 100-HR-3 aquifer tube installations were proposed for the fall of 2003. Permitting delays and severe weather delayed the start of field work until January 2004. Results will be included in the CY04 semi-annual technical memorandum.

2.2 100-HR-3 OPERABLE UNIT TREATMENT SYSTEM PERFORMANCE

This section describes the 100-HR-3 pump-and-treat system operation and sampling activities. Information presented includes system availability, changes to the system configuration, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and short-term contaminant comparisons. Additional operational details are found in the associated appendices, as specified in the text.

2.2.1 System Modification/Operation

No significant capital improvements or modifications where performed on the pump-and-treat system in CY03. Figure 2-4 provides a system schematic, detailing the current configuration.

A summary of operational parameters and total system performance for the 100-HR-3 OU for CY03 is presented in the following table:

Total processed groundwater (million L):		
	CY03	**Since Startup 1997**
100-D Area	237.4	1,035.1
100-H Area	179.2	913.2
Total	**416.6**	**1,948.3**
Total mass of hexavalent chromium removed (kg):		
	CY03	**Since Startup 1997**
100-D Area	38.33	168.93
100-H Area	4.66	35.06
Total	**42.99**	**203.99**

2003 operational parameters:	
Removal efficiency (% by mass)	93.8
Waste generation (m^3)[a]	80.5
Low-level radioactive waste generation (m^3)	4.5
Regenerated resin installed (m^3)	43.0
New resin installed (m^3)	36.2
Number of resin changeouts	35
2003 system availability:	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	173
Planned operations (hours)	8,587
Unscheduled downtime (hours)	16.5
Total time on-line (hours)	8,570.5
Total availability (%)	97.8
Scheduled system availability (%)	99.8

[a] Each ion-exchange vessel contains 2.3 m^3 of ion-exchange resin.

The operational and system highlights for CY03 are discussed below:

- A total of 416.6 million L (combined) were processed in CY03. This is larger than the 350.5 million L processed in CY02. The larger volume of water processed resulted in a total of 42.9 kg of hexavalent chromium being recovered in CY03 compared to the 32.02 kg recovered in CY02.
- The average removal efficiency [(influent – effluent)/influent] for CY03 was 93.8%, which is the same as CY02 (Figure 2-5).
- The 100-D Area influent hexavalent chromium concentration average of 174.5 μg/L in CY03 was slightly higher than the CY02 average of 160 μg/L.
- The average CY03 hexavalent chromium concentration of 27.9 μg/L for the 100-H Area influent was slightly higher than the 25.5 μg/L reported in CY02. Trend plots of CY03 influent and effluent concentrations are presented in Figure 2-6.
- Effluent concentrations were consistently below the maximum allowable concentration of 50 μg/L for the entire CY03 reporting period.
- Scheduled system availability for CY03 was 99.8% (total possible run-time - unscheduled downtime)/total possible run-time), which was the same as the 99.8% reported in CY02. The total availability for CY03 was 97.8% (total possible run-time - scheduled and unscheduled downtime)/total possible run-time). This is slightly higher than the 97% on-line availability reported for CY02. The monthly on-line percentages and events impacting system availability for the reporting period are presented in Figure 2-7.
- The river level in CY03 continued at near-average levels, allowing extraction wells to maintain their productivity. This resulted in a slightly larger volume of processed water for CY03.

During CY03, 35 spent ion-exchange vessels were changed out. The resin changeouts were performed based on a maximum operating time. The purpose of the limits was to reduce the amount of resin requiring regeneration by maximizing its operational life, while limiting the possibility of saturating the resin and creating a low-level radioactive waste that could not be shipped offsite for reprocessing. The time limits are area-dependent because of the different chemical/radiological characteristics of native groundwater at each well. For the 100-D and 100-H Areas, the time limits are approximately 120 and 90 days, respectively. These time limits were not implemented until late in CY02.

During CY03, the vessels that were changed out equate to 80.5 m^3 of spent resin, which was higher than the 66.7 m^3 reported in CY02. Of the total resin removed in CY03, 4.5 m^3 represents low-level radioactive waste that was disposed at the Environmental Restoration Disposal Facility. This was a smaller volume than the 14.5 m^3disposed in CY02. The change in the volume of spent resin can be attributed to a greater volume of water processed during the time period. The difference in volume of radioactive waste is due to lowering of the waste designation for the "A" process train. This allowed for more reprocessing of spent resin rather than designation as waste.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates can be found in Appendix B.

2.3 AQUIFER RESPONSE IN THE 100-D AREA

This section describes the general hydrogeologic conditions in the 100-D Area, the numerical modeling conducted to evaluate the extraction well network, and the changes in contaminant concentrations in monitoring wells.

2.3.1 Hydrogeologic Conditions at the 100-D Area

The hydrogeologic conditions at the 100-D Area are summarized below:

- The most prevalent groundwater flow direction is northwest, as shown in Figure 2-8. During spring months, the river elevation is generally higher because of increased run-off and to provide more irrigation water and aid fish migration. This flow reversal from northwest to southeast is clearly shown in Figure C-5 of Appendix C, where the May and June 2003 river elevations are higher than near-river wells.
- The average November 2003 river-stage elevation was 115.38 m (378.5 ft) compared to the average 1991 to 2003 November river-stage elevation of 115.19 m (377.9 ft).
- The maximum November 2003 hydraulic gradient was 0.002 toward the northwest based on the groundwater surface elevation contours shown in Figure 2-8.
- The estimated maximum groundwater flow velocity at the 100-D Area was 0.24 m/day (0.79 ft/day) based on a hydraulic conductivity of 16.5 m/day (54.13 ft/day), porosity of 0.14, and a gradient of 0.002.
- The average 2003 extraction well pumping rates ranged from a low of 85.9 L/min (22.4 gallons per minute [gpm]) in well 199-D8-53 to a high of 185.8 L/min (49.1 gpm) in well 199-D8-68. This is slightly lower than the 109.7 L/min (29 gpm) to 125.2 L/min (33.1 gpm) reported in 2002 (see Appendix B).
- Leakage from the 182-D reservoir has created a groundwater mound and increased the hydraulic gradient. This resulted in displacement of the chromium plume radially away from the reservoir and mixing of groundwater and leaked river water near the reservoir.

2.3.2 Numerical Modeling and Field Validation of Zone of Influence

A summary of the numerical modeling results supporting the 100-HR-3 pump-and-treat system in the 100-D Area is as follows:

- The original hexavalent chromium pump-and-treat plume (from the D and DR Reactors, north to the Columbia River) is within the capture zone of the existing extraction well network, as shown in Figures 2-9 and 2-10.
- A portion of the hexavalent chromium plume north of the 182-D reservoir is located outside the capture zone of the existing extraction well network (see Figures 2-9 and 2-10). This portion of the plume is not flowing through the existing ISRM treatment zone.
- A list of the modeled water table elevations and average modeled flow rates is presented in Table 2-1.

- A measured drawdown/buildup analysis was not necessary to support the 2003 modeled results because of the strong similarity between 2002 and 2003 extraction well pumping rates, river stage, and hydraulic gradient. This analysis may be conducted in future years if conditions vary significantly.

2.3.3 Contaminant Monitoring in the 100-D Area

This section summarizes and interprets the analytical results obtained from groundwater wells included in the interim remedial action and OU monitoring programs in the 100-D Area. Data are stored in the Hanford Environmental Information System (HEIS) database.

The principal contaminant of concern (COC) in the 100-D Area is hexavalent chromium. The RAO for reduction of chromium concentration is 22 µg/L at the compliance wells. Strontium-90, tritium, and nitrate are co-contaminants that are being actively monitored but are not present in concentrations that exceed ecological risk criteria. In addition, sulfate is a contaminant of interest because it exceeds secondary drinking water standards in a limited number of wells. Institutional controls, which are implemented to satisfy a RAO, limit human exposure to hexavalent chromium and the co-contaminants.

Section 2.3.3.1 discusses the results of chromium monitoring, and Section 2.3.3.2 discusses the results of co-contaminant monitoring. Locations of the monitoring wells and aquifer sampling tubes are shown in Figure 2-2.

The CY03 highlights are as follows:

- Fall 2003 chromium concentrations decreased or were stable in six of seven extraction wells and compliance wells when compared to fall 2002 concentrations but were not below the RAO. Chromium concentrations increased in well 199-D8-54 to 168 µg/L in the fall of 2003, which is an increase of 23%.
- Chromium concentrations up to 1,830 µg/L have been detected in well 199-D5-41, which is an increase of 267% from last year. This well is located outside the current extraction well capture zone. In addition, well 199-D5-20, which is located approximately 150 m (492 ft) from the Columbia River, was characterized by 1,325 µg/L chromium in the fall of 2003 compared to 627 µg/L chromium in 2002.
- Strontium-90 and tritium concentrations were less than the maximum contaminant levels (MCLs) in all 100-D Area samples collected during CY03.

2.3.3.1 100-D Area Chromium Monitoring Results

Chromium concentrations are monitored in 4 of the 100-D Area pump-and-treat extraction wells, 2 compliance wells, and 29 monitoring wells. Chromium increased 23% from CY02 to CY03 in extraction well 199-D8-54A; however, chromium concentrations did not change more than 20% in the other extraction wells or compliance wells, as shown in the table below:

Well	Type	Fall 2002 Cr (μg/L)	Fall 2003 Cr (μg/L)	Percent Change[b]
199-D8-53	Extraction	146	143	-2
199-D8-54A	Extraction	137[a]	168	+23
199-D8-68	Extraction	106	110[a]	+4
199-D8-69	Compliance	81	71	-12
199-D8-70	Compliance	150[a]	143	-5
199-D8-72	Extraction	537	533	-1

[a] Average value.
[b] *Percent change = (2002 - 2003)/2002 x 100%.*

Chromium concentrations continued to increase significantly northwest of D Reactor and north of the 182-D reservoir. This area includes wells 199-D5-20 and 199-D5-41, which were discussed previously. It is possible that the chromium increases originate from an unknown source between the former dichromate transfer station and D Reactor, or simply movement of an existing but previously undetected plume. The following table presents data for those wells in which chromium concentrations increased more than 20%:

Well	Type	Fall 2002 Cr (μg/L)	Fall 2003 Cr (μg/L)	Percent Change[b]
199-D5-17	Monitoring	12.6	15.2	+21
199-D5-20	Monitoring	627	1325[a]	+111
199-D5-41	Monitoring	498	1830	+267
199-D5-42	Monitoring	33.8	45.9	+36

[a] Average value.
[b] Percent change = (2002 - 2003)/2002 x 100%.

Figure 2-8 displays the fall 2003 100-D Area chromium plume generated from samples collected in November and December 2003. The values displayed include filtered total chromium and hexavalent chromium concentrations.

Five aquifer sampling tubes were sampled downgradient of the 100-D pump-and-treat system during January 2003. These results are out of sequence with the fall 2003 well sampling, therefore the data are not included on the 100-D plume maps. A summary of aquifer tube sampling results for CY03 is provided in Appendix E.

2.3.3.2 100-D Area Co-Contaminant Monitoring Results

The 100-D Area co-contaminants are strontium-90, tritium, and nitrate (DOE-RL 1997). Sulfate is a constituent of interest.

- Strontium-90 concentrations were measured in samples from four extraction wells, two compliance wells, and two monitoring wells. None of the samples collected during 2003 or 2002 contained strontium-90 above the 8 pCi/L MCL.
- Tritium concentrations were measured in samples from 4 extraction wells, 2 compliance wells, and 14 monitoring wells. None of the samples collected in 2003 contained tritium above the 20,000 pCi/L MCL.

- Nitrate was detected above the 45 mg/L MCL in 15 of 30 wells during 2003 compared to 7 wells above the MCL in 2002. The maximum 2003 nitrate concentration was 74.4 mg/L in well 199-D5-16. The highest concentrations of nitrate were detected in samples from wells located around the D and DR Reactors and south and west of the 182-D reservoir.
- Sulfate was not detected at or above the 250 mg/L secondary MCL in any of the 16 wells sampled during 2003 or 2002. The maximum concentration detected during 2003 sampling was 151 mg/L in well 199-D5-16.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

2.4 AQUIFER RESPONSE IN THE 100-H AREA

2.4.1 Hydrogeologic Conditions in the 100-H Area

The hydrogeologic conditions in the 100-H Area are summarized below:

- The most prevalent groundwater flow direction is northeast, as shown in Figure 2-11. During spring months, the river elevation is generally higher because of increased run-off and to provide more irrigation water and aid fish migration. This flow reversal from northeast to southwest is clearly shown in Figure C-6 of Appendix C, where the May and June 2003 river elevations are higher than near-river wells.
- The average November 2003 river-stage elevation was 115.38 m (378.5 ft) compared to the average 1991 to 2003 November river-stage elevation of 115.19 m (377.9 ft).
- The maximum November 2003 hydraulic gradient was 0.002 toward the northwest based on the Figure 2-11 groundwater surface elevation contours.
- The estimated groundwater flow velocity range at the 100-H Area was 0.1 to 2.7 m/day (0.33 to 8.9 ft/day) based on a hydraulic conductivity of 15 to 140 m/day (49.2 to 459.3 ft/day), porosity of 0.2, and a gradient of 0.002.
- The average 2003 extraction well pumping rates ranged from 107.5 L/min (28.4 gpm) in well 199-H3-2A to 32.2 L/min (8.5 gpm) in well 199-H4-12A. This compares to a range of 88.5 L/min (23.4 gpm) to 42 L/min (11 gpm) in 2002.

2.4.2 Numerical Modeling

A summary of the numerical modeling results supporting the 100-HR-3 pump-and-treat system in the 100-H Area follows:

- The original 100-H hexavalent chromium pump-and-treat plume has been greatly reduced in area and the remainder is within the capture zone of the existing extraction well network, as shown in Figures 2-12 and 2-13.
- There is a modeled gap in the capture zone between extraction wells 199-H4-12A and 199-H4-65 (see Figure 2-11). This gap is largely because of insufficient saturated Hanford formation thickness in the area of extraction well 199-H4-65, resulting in low flow rates and discontinuous operation of the well.

- A list of the modeled water table elevations and average modeled flow rates is provided in Table 2-1.
- A measured drawdown/buildup analysis was not necessary to support the 2003 modeled results because of the strong similarity between 2002 and 2003 extraction well pumping rates, river stage, and hydraulic gradient. This analysis may be conducted in future years if conditions vary significantly.

2.4.3 Contaminant Monitoring in the 100-H Area

This section summarizes and interprets analytical results obtained from groundwater monitoring wells and aquifer sampling tubes supporting the 100-H Area pump-and-treat remedial action and the 100-HR-3 OU monitoring program. Section 2.4.3.1 includes a discussion of the chromium monitoring results. The RAO for chromium concentrations is 22 µg/L at the compliance wells. Section 2.4.3.2 includes a discussion about monitoring results for the remedial action co-contaminants strontium-90, tritium, nitrate, technetium-99, and uranium.

The CY03 highlights are as follows:

- The highest chromium concentrations were downgradient of the former 183-H solar evaporation basins, near monitoring well 199-H4-3, in which concentrations were detected up to 78 µg/L.
- The maximum November 2003 compliance well chromium concentration was 61 µg/L in well 199-H4-5. Other compliance well concentrations ranged from 19 to 43 µg/L chromium.
- The November 2003 chromium concentration in extraction well 199-H3-2A was 6.45 µg/L. Concentrations in this well were more than 100 µg/L in 1997 when pump-and-treat operations began, but annual November values have been below the RAO for the past 5 years.
- The November/December 2003 chromium concentrations in the other 100-H Area extraction wells ranged from 29 µg/L in well 199-H4-7 to 76 µg/L in well 199-H4-12A.
- Fewer well samples were characterized by co-contaminant concentrations that were above MCLs compared to November 2002.

2.4.3.1 100-H Area Chromium Monitoring Results

Chromium is monitored in the 100-H Area in 5 extraction wells, 4 compliance wells, and 18 monitoring wells (Figure 2-3). Figure 2-11 illustrates the fall 2003 100-H chromium plume and associated historical chromium trends.

As shown below, fall 2003 chromium concentrations varied when compared to the fall of 2002. Chromium concentrations decreased in two of five extraction wells and increased in three of four compliance wells. Chromium concentration increases in well 199-H4-12B, screened in the bottom part of the unconfined aquifer, mirrored the increases in well 199-H4-12A.

Significant decreases in chromium concentrations were observed at seven monitoring wells across the 100-H Area. Chromium concentrations generally increased in the northern part of the 100-H plume, namely in extraction wells 199-H4-15A and 199-H4-12A and in compliance wells 199-H4-5 and 199-H4-64. The table below summarizes changes in chromium concentrations from 2002 to 2003 in 100-H extraction wells, compliance wells, and monitoring wells with chromium above 22 µg/L or changes greater than 20%:

Well	Type	Fall 2002 Cr (µg/L)	Fall 2003[a] Cr (µg/L)	Percent Change[b]
199-H3-2A	Extraction	16	5	-69
199-H4-7	Extraction	44	29	-34
199-H4-11	Extraction	31	37	+19
199-H4-12A	Extraction	50	76	+52
199-H4-15A	Extraction	46	65	+41
199-H4-4	Compliance	65	38	-42
199-H4-5	Compliance	56.3	61	+8
199-H4-63	Compliance	49	19	-61
199-H4-64	Compliance	40	43	+8
199-H4-12B	Monitoring	49	69	+41
199-H4-14	Monitoring	32	41	+28
199-H4-3	Monitoring	73	78	+7
199-H4-8	Monitoring	38	19	-50
199-H4-9	Monitoring	51	35.6	-30
199-H4-13	Monitoring	31	22	-29
199-H4-16	Monitoring	16	9	-44
199-H4-17	Monitoring	32	17	-47
199-H4-18	Monitoring	27	20	-26
199-H5-1A	Monitoring	12	7	-42

[a] Remedial action objective is 22 µg/L.
[b] (Fall 2003 - fall 2002)/fall 2002 x 100%.

The results displayed are from samples collected in November and December 2003. The values displayed are filtered total chromium and hexavalent chromium concentrations.

Five aquifer sampling tubes were sampled downgradient of the 100-D pump-and-treat system during January 2003. These results are out of sequence with the fall 2003 well sampling, therefore the data are not included on the 100-H plume maps. A summary of aquifer tube sampling results for CY03 is provided in Appendix E.

2.4.3.2 100-H Area Co-Contaminant Monitoring Results

The 100-H Area co-contaminants are strontium-90, technetium-99, uranium, tritium, and nitrate (DOE-RL 1997). Further discussion on these co-contaminants is provided below:

- Strontium-90: Two of eight well samples analyzed for strontium-90 in November 2003 were above the 8 ρCi/L MCL. In 2002, five well samples were above 8 ρCi/L. The two wells above the strontium-90 MCL are located downgradient of the former 107-H retention basin and the former 116-H-1 liquid waste disposal trench. Both of these facilities were excavated in 1999-2000 and backfilled in 2001.

Well	Type	Fall 2002 Sr-90 (pCi/L)	Fall 2003 Sr-90 (pCi/L)	Percent Change[a]
199-H4-63	Compliance	20.2	24.6	+22
199-H6-1	Monitoring	8.2	9.26	+13

[a] (2003 – 2002)/2002 x 100%.

- Technetium-99: All eight well samples analyzed for technetium-99 were below the 900 pCi/L MCL. In November 2002, the sample from well 199-H4-9 contained technetium-99 at 986 pCi/L, the only time above the MCL. The November 2003 sample result for this well was characterized by 169 pCi/L of technetium-99 compared to 986 pCi/L in November 2002, an 83% decrease.
- Uranium: Nine of 10 well samples analyzed for uranium in 2003 were characterized by results below the 30 µg/L MCL. Monitoring well 199-H4-3, which is downgradient of the former 183-H solar evaporation basins, was characterized by 54.3 µg/L total uranium, down from 119 µg/L in 2002.
- Tritium: All 18 well samples analyzed for tritium were below the 20,000 pCi/L MCL. The maximum tritium concentration was 3,720 pCi/L in well 199-H6-1.
- Nitrate: Twenty well samples were analyzed for nitrate in November 2003, and five results were above the 45 mg/L MCL. Three of the five wells where nitrate was present above the MCL are located downgradient of the former 183-H solar evaporation basins, which is a possible source; however, nitrate is a widespread contaminant in the 100 Area and Hanford Site groundwater. The table below summarizes nitrate concentrations in 100-H wells above the 45 mg/L MCL:

Well	Type	Nov. 2002 NO_3 (mg/L)	Nov. 2003 NO_3 (mg/L)	Percent Change[a]
199-H4-3	Monitoring	255	192	-25
199-H4-4	Compliance	31	60.6	+95
199-H4-7	Extraction	49.6	46.5	-6
199-H4-9	Monitoring	474	112	-76
199-H6-1	Monitoring	45.6	46	+1

[a] (2003 - 2002)/2002 x 100%.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

2.5 QUALITY CONTROL RESULTS FOR 100-D AND 100-H MONITORING DATA

The QC results for the 100-HR-3 sampling activities involve field or offsite laboratory testing for hexavalent chromium or total chromium.

The highlights of QC data for CY03 100-D and 100-H Area sampling are summarized below. Tables listing the complete QC results are found in Appendix F.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent of Pairs <20% RPD
Field replicates (hexavalent chromium)	27	27	100%
Field/offsite laboratory splits (hexavalent chromium)	32	27	84%
Offsite laboratory replicates (total chromium)	8	6	75%
Offsite laboratory splits (total chromium)	4	4	100%

RPD = relative percent difference

The U.S. Environmental Protection Agency's (EPA's) *Laboratory Data Validation Functional Guidelines for Evaluating Inorganic Analyses* (EPA 1988) functional guideline for field-tested replicates is ±20%. All field replicates were within acceptable limits. There are no functional guidelines for split results or offsite laboratory replicates, but the results correlated well based on the relative percent differences (RPDs).

2.6 CONCEPTUAL MODEL

2.6.1 Update of the 100-D Area Conceptual Model

This section describes the sources of the chromium contamination in the 100-D Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0. For convenience, hexavalent chromium is simply referred to as "chromium" in this text, unless noted otherwise.

Coolant water containing sodium dichromate in solution leaked from cooling water retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to the groundwater. In addition, radiologically contaminated coolant water was disposed in process effluent trenches, french drains, or cribs. Chromic acid, H_2CrO_4, is a strong oxidizer that was used to decontaminate and clean reactor equipment, and the contaminated solution was then disposed to french drains. Transfer lines leading from the sodium dichromate transfer station to the reactors may have leaked to the vadose zone. These transfer lines are located near and parallel to raw water lines. A summary of waste sites that may be a source of chromium contamination in the 100-D/DR Reactor area is presented in *Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units* (BHI 1996).

Known disposal and spill sites have been investigated by boring from the surface and collecting samples to detect near-surface contamination. An investigation was conducted in 2000 around the sodium dichromate transfer station in the 100-D Area (PNNL 2000). This investigation was not successful in locating significant near-surface chromium sources.

Another soil investigation was conducted in November 2003 during drilling of monitoring well 199-D5-34. Samples were collected at 1.5-m (5-ft) intervals from the surface to the water table at a depth of 33.5 m(110 ft). Hexavalent chromium was not detected in any of the soil samples. This well was located adjacent to a french drain that was a suspected disposal site for excess sodium dichromate.

Typical unconfined aquifer hydrostratigraphy in the 100-D Area includes the Hanford formation, the Ringold Unit E, and the Ringold Upper Mud Unit. The thickness of the Ringold Unit E varies significantly from north to south, and it may have been eroded locally in the north so the Hanford formation was deposited directly on the Ringold Upper Mud Unit. Two of the 100-D pump-and-treat extraction wells (199-D8-53 and 199-D8-54A) appear to be located where the Hanford formation is deposited directly on the Ringold Upper Mud Unit. The unconfined aquifer in these wells is located in Hanford formation sand and gravel with locally silty intervals. These wells are characterized by high well efficiency (e.g., significant production per foot of drawdown).

In the southern part of the 100-D Area, the Hanford formation was deposited on the Ringold Unit E. The unconfined aquifer in this area is within the Ringold Unit E composed of more consolidated silt, sand, and gravel with locally cemented intervals. The wells associated with the ISRM were screened in Ringold Unit E sediments and almost universally are not as efficient (e.g., less production per foot of drawdown) as those wells screened in the Hanford formation. A more detailed description of the 100-D Area stratigraphy is presented in BHI (1996) and DOE-RL (1996b).

Groundwater flow in the 100-D Area is predominantly to the north in the pump-and-treat area and northwest in the southern part of the 100-D Area, near the ISRM. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices associated with the 182-D Reservoir, and variation in the hydrostratigraphy.

Groundwater flow is generally toward the Columbia River (gaining stream), except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (losing stream). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe reservoir elevations.

Facilities that have most recently affected the groundwater flow regimes in the 100-D Area include the 120-D-1 Ponds and the 182-D reservoir. Normal disposal practices and leakage from these facilities may have been responsible for mounding between the reactor buildings and the Columbia River. The 120-D-1 Ponds were closed to disposal in 1995. The 182-D reservoir was emptied from November 2002 to April 2003 and remained empty until mid-July 2003 when it was filled to capacity. Reservoir construction joints were repaired while the reservoir was empty. The fall 2003 water table elevation map suggests that the repairs were not effective because a groundwater mound is present in the area surrounding the 182-D reservoir.

In addition, the hydrostratigraphy also influences flow velocity and direction. Northeast of the ISRM barrier, an eroded channel through the Ringold Upper Mud Unit has been filled with Ringold Unit E sediments. The Ringold Unit E sediments have a higher hydraulic conductivity than the Ringold Upper Mud materials, and therefore may act as a preferential flow channel to the north.

The original target area of the pump-and-treat system, which came on-line in 1997, was a plume which extended from the 100-D and 100-DR Reactor areas, north to the Columbia River (Figure 2-14). The highest chromium concentrations were about 1,300 µg/L in wells located north of the reactors. The 1997 extraction well concentrations were approximately 300 to 400 µg/L. The high-concentration areas were within the modeled capture zone of the extraction wells. The capture zone of the pump-and-treat extraction wells was expanded in May 2002 with the addition of well 199-D8-72 and the conversion of compliance well 199-D8-68 into an extraction well. These wells extended capture of the north (pump-and-treat) plume to the west to contain other high chromium areas (Figures 2-9 and 2-10).

Additional site characterization since 1995 led to the discovery of the southwest 100-D plume, which was outside the capture zone of the pump-and-treat extraction wells. The ISRM barrier was built to control this southwest plume. The southwest 100-D plume was separated from the north plume (i.e., the pump-and-treat plume) by groundwater mounds created by disposal to the 120-D-1 Ponds, leakage from the 182-D reservoir, and possibly by injection into wells south of the DR Reactor during 1995 during the pilot-scale pump-and-treat test.

Changes in flow direction caused by mound dissipation have resulted in the north plume and southwest plumes coalescing (Figure 2-14). In addition, chromium concentrations are increasing in wells near the Columbia River, outside the expanded capture zone of the 100-D pump-and-treat system, and north of the ISRM. Well 199-D5-20 in the southwest portion of the plume has experienced a large increase in chromium to 1,325 µg/L. This well is located approximately 150 m (492 ft) from the Columbia River.

The pump-and-treat system has removed approximately 170 kg of chromium from the unconfined aquifer beneath the 100-D Area. Chromium concentrations in the original extraction wells have declined to 143 and 168 µg/L in November 2003, compared to 300 to 400 µg/L in 1997. In addition, chromium concentrations have declined from 1,300 µg/L, to 279 µg/L and 333 µg/L, in the wells north of the reactors (namely in wells 199-D5-14 and 199-D5-15). These reductions in chromium mass indicate that progress has been made during the last year toward meeting the RAOs identified in the interim ROD (EPA et al. 1996).

The highest remaining concentrations are in the southwest plume area, notably in well 199-D5-39, where chromium has been measured above 4,500 µg/L. The source of this plume may be the former sodium dichromate/chromic acid transfer station upgradient (east) of well 199-D5-39.

Three monitoring wells were installed in the fall of 2003 to determine the source of the chromium plume and aid in configuring the plume. Reservoir leakage causing mixing strongly affected water chemistry in the two wells near the reservoir in wells 199-D5-33 and 199-D5-34. The leakage is currently under control and water chemistry in these two wells may normalize and provide information about potential sources, namely the former sodium dichromate transfer station.

2.6.2 Update of the 100-H Area Conceptual Model

This section describes the sources of the chromium contamination in the 100-H Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium readily adsorbs to soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0.

Coolant water containing sodium dichromate in solution leaked from cooling water retention basins and large-diameter underground piping, introducing chromium to the soil column and ultimately to groundwater. Specific facilities that have leaked include the 183-H solar evaporation basins and the 107-H retention basins. A summary of waste sites, which may be a source of chromium contamination in the 100-H Reactor area, is provided in BHI (1996).

The 100-D Area may have been the source of a chromium plume west of the 100-H Area. Leaking cooling water retention basins created a significant mound of sodium dichromate contaminated water that flowed radially, including east, from the 100-D retention basin area. Two of the 600 Area wells, namely wells 699-96-43 and 699-97-43 (located upgradient [west] of the 100-H Area), have been characterized by chromium concentrations near 100 μg/L since the start of pump-and-treat operations. This plume may have traveled from the 100-D Area.

Typical unconfined aquifer hydrostratigraphy in the 100-H Area includes the Hanford formation and the Ringold Upper Mud Unit. The unconfined aquifer is located in the saturated Hanford formation with the top of the Ringold Upper Mud Unit as its base. The thickness of the unconfined aquifer at the 100-H area varies significantly, as shown in Figure 2-15 (isopach map of saturated Hanford formation). Extraction wells located near the Columbia River are characterized by 3 to 4.5 m (10 to 15 ft) of saturated Hanford formation. As shown in Figure 2-15, the saturated thickness of the Hanford formation thins to as little as 0.6 m (2 ft) in the 600 Area, which is west of the 100-H Area (well 699-96-43). Additional details regarding 100-H Area hydrostratigraphy are found in BHI (1996) and DOE-RL (1996b).

Groundwater flow in the 100-H Area is predominantly to the northeast. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices (especially injection wells), and hydrostratigraphy.

Groundwater flow generally is toward the Columbia River (gaining stream), except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the stage of the river and may reverse the flow direction (losing stream). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe reservoir elevations.

Leakage from the former 107-H retention basins created a groundwater mound in the 100-H Area. This mound could have pushed chromium-contaminated groundwater to the west. These basins were in use until about 1965, and any mounding has since dissipated.

Hydrostratigraphy has a strong influence on aquifer conditions in the 100-H Area. The minimal thickness of the saturated Hanford formation west of the 100-H Area (0.6 to 2.1 m [2 to 6.9 ft]) in wells 699-96-43 and 699-97-43 restricts the flow into the 100-H Area. In addition, a thin aquifer along the Columbia River limits drawdown in extraction wells and therefore restricts pumping rates.

The original target area of the pump-and-treat system, which came on-line in 1997, was a wedge-shaped, 100 μg/L chromium isopleth that extended to well 199-H3-2A and was bounded along the shoreline by the 50 μg/L chromium isopleth (Figure 2-16). Maximum concentrations within this target area were more than 100 μg/L in well 199-H3-2A. This high-concentration area around well 199-H3-2A moved to the near-river wells in subsequent years.

The November 2003 maximum concentrations in wells within the original 100-H Area target area were 76 μg/L and 65 μg/L in extraction wells 199-H4-12A and 199-H4-95A, respectively. The November 2003 chromium concentration in extraction well 199-H3-2A was 5 μg/L.

The capture zone of the original extraction wells included a gap between extraction wells 199-H4-12A and 199-H4-11. This gap was closed in 2000 with the addition of well 199-H4-65. However, limitations on pumping rates in this well and adjacent extraction wells caused by lowered water levels have caused incomplete hydraulic capture in this area.

Mounding caused by injection wells 199-H3-3, 199-H3-4, and 199-H3-5 has had the effect of diluting contaminant concentrations now present in monitoring wells around the injection field and in extraction well 199-H3-2A.

The pump-and-treat system has removed approximately 35 kg of chromium from the aquifer since startup in 1997. The total remaining chromium mass is not known. However, the annual chromium mass removed has decreased from 5.5 kg in 1999 to 4.7 kg in 2003; similarly, average influent concentrations were 45 μg/L in 1999 compared to 27.9 μg/L in 2003.

2.7 CONCLUSIONS

The pump-and-treat system continues to make significant progress toward remediating the contaminant plume along the 100-D and 100-H Area shorelines by extracting groundwater before it reaches the river. In addition, human receptors are protected onsite using institutional controls. Details regarding the operation of the existing pump-and-treat system will be useful in evaluating system upgrades and modifications.

- ***RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River. The RAO for compliance wells is 22 μg/L based on the 11 μg/L ambient water quality criterion in place at the time of the signing of the ROD and a 1:1 dilution ratio.***

  100-D Area:

  - Approximately 237.4 million L of groundwater were treated during CY03, and 38.3 kg of hexavalent chromium were removed.
  - Chromium concentrations decreased or were stable from November 2002 to November 2003 in six of seven 100-D Area extraction wells and compliance wells. However, chromium concentrations were not below the 22 μg/L RAO in any of the extraction or compliance wells.
  - Chromium concentrations to 1,325 μg/L were detected in well 199-D5-20. This represents an increase of 111% from last year. This well is located within 150 m (492 ft) of the Columbia River and outside the extraction well capture zone. In addition, well 199-D5-41 was characterized by 1,830 μg/L chromium in 2003, which is a 267% increase from 2002.
  - Strontium-90 and tritium concentrations were less than the MCLs in all 100-D Area samples collected during CY03.
  - Plume and water table surface maps indicate that the hydraulic barrier separating the northern plume contained by the pump-and-treat system and the southwest plume controlled by the ISRM has dissipated, and the plumes appear to have merged.

However, newly discovered leaks at the 182-D reservoir may again alter areal distribution of the plume.

- Monitoring wells were installed near the 182-D reservoir to better delineate the chromium plume and groundwater mounding in this area. These wells were designed so they can be used as extraction wells if needed.
- Numerical modeling results indicate that the extraction well network is containing the northern portion of the 100-D chromium plume. This is the portion of the plume originally targeted by the interim action ROD (EPA et al. 1996) and not the southwest 100-D chromium plume targeted by the ISRM.

<u>100-H Area</u>:

- Approximately 179.2 million L of groundwater were treated in CY03, and 4.66 kg of hexavalent chromium were removed.
- The highest chromium concentrations were downgradient of the former 183-H solar evaporation basins, near monitoring well 199-H4-3, which had concentrations up to 78 µg/L.
- The maximum November 2003 compliance well chromium concentration was 61 µg/L in well 199-H4-5. Other compliance well concentrations ranged from 19 to 43 µg/L chromium.
- The November 2003 chromium concentration in extraction well 199-H3-2A was 6.5 µg/L. Concentrations in this well were more than 100 µg/L in 1997 when pump-and-treat operations began, but annual November values have been below the RAO cleanup goal for the past 5 years.
- November/December 2003 chromium concentrations in the other 100-H Area extraction wells ranged from 29 µg/L in well 199-H4-7 to 76 µg/L in well 199-H4-12A.
- Fewer well samples had co-contaminant concentrations that were above MCLs compared to November 2002.
- Numerical modeling results indicate that the extraction well network generally contains the plume along much of the 100-H Area shoreline. Gaps in capture are due largely to lowered pumping rates in some wells because of a thin saturated aquifer and low water levels.

• ***RAO #2: Protect human health by preventing exposure to contaminants in groundwater.***

Results: The interim remedial action ROD establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

- Access control and visitor escorting requirements
- Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)

- Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
- Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls was presented in the *2003 Sitewide Institutional Control Annual Assessment Report for the Hanford CERCLA Response Actions* (DOE-RL 2003). The findings of this report indicate that institutional controls were maintained to prevent public access as required.

- ***RAO #3: Provide information that will lead to a final remedy.***

  Results: The following information will be used in determining the effectiveness of ongoing operations in reaching a final remedy:

  - Treatment cost: Treatment cost for the period was $2,012,000. At a yearly production rate of 416.6 million L and 42.9 kg of chromium removed, the treatment cost equates to about $0.005/L, or $47/g of chromium removed. These costs are significantly lower than the $0.008/L, or $85/g of chromium removed in CY02.
  - System efficiency: Removal efficiency of the treatment system was maintained at 93.8% in CY03.
  - Hydraulic impact: Numerical modeling was used to estimate the effectiveness of the capture and containment of the plume. The model suggests that the 100-D Area system captures groundwater from the targeted area that would otherwise discharge into the Columbia River. At the 100-H Area, the model suggests that the system captures most groundwater from the targeted area, except for a gap between extraction wells 199-H4-65 and 199-H4-12A.
  - Effectiveness of contaminant removal in aquifer: During this reporting period, more than 416.6 million L of water were treated from the 100-HR-3 OU, which resulted in the removal of 42.9 kg of chromium. Since initiation of the system in July 1997, more than 1.94 billion L of water have been treated, resulting in the removal of approximately 203.9 kg of chromium from the 100-HR-3 aquifer.
  - Maintain data: Pertinent data have been maintained in the HEIS database and the project-specific database.
  - System availability: Total system availability for CY03 continued at 99.8% (time on-line/total hours during the year – scheduled outages). The on-line availability was 97.8% (time on-line/total hours during the year). This is a slight increase from the on-line availability reported for CY02 (97%).

2.8 RECOMMENDATIONS

100-D Area:

- Perform continuous water-level monitoring near the 182-D reservoir to measure the effects and magnitude of reservoir leakage on the hydraulic flow regime and the impact on the chromium plume area's extent and movement.
- Implement remedial actions to address the high-concentration chromium plume between the 100-D pump-and-treat system and the ISRM treatment zone.

100-H Area:

- Evaluate the placement of injection wells closer to the greater-than-50 μg/L portion of the plume to increase the hydraulic gradient and accelerate remediation of the aquifer. This evaluation will use a cost/benefit analysis for impacts to the cleanup schedule, hydrogeology, treatment cost, and system efficiency and effectiveness.
- Evaluate the long-term use of extraction well 199-H4-65 as part of the 100-H extraction well network. Redesign or replace this well if it is necessary for capture, or reconfigure it as a monitoring well.

Figure 2-1. Location of the 100-HR-3 Operable Unit.

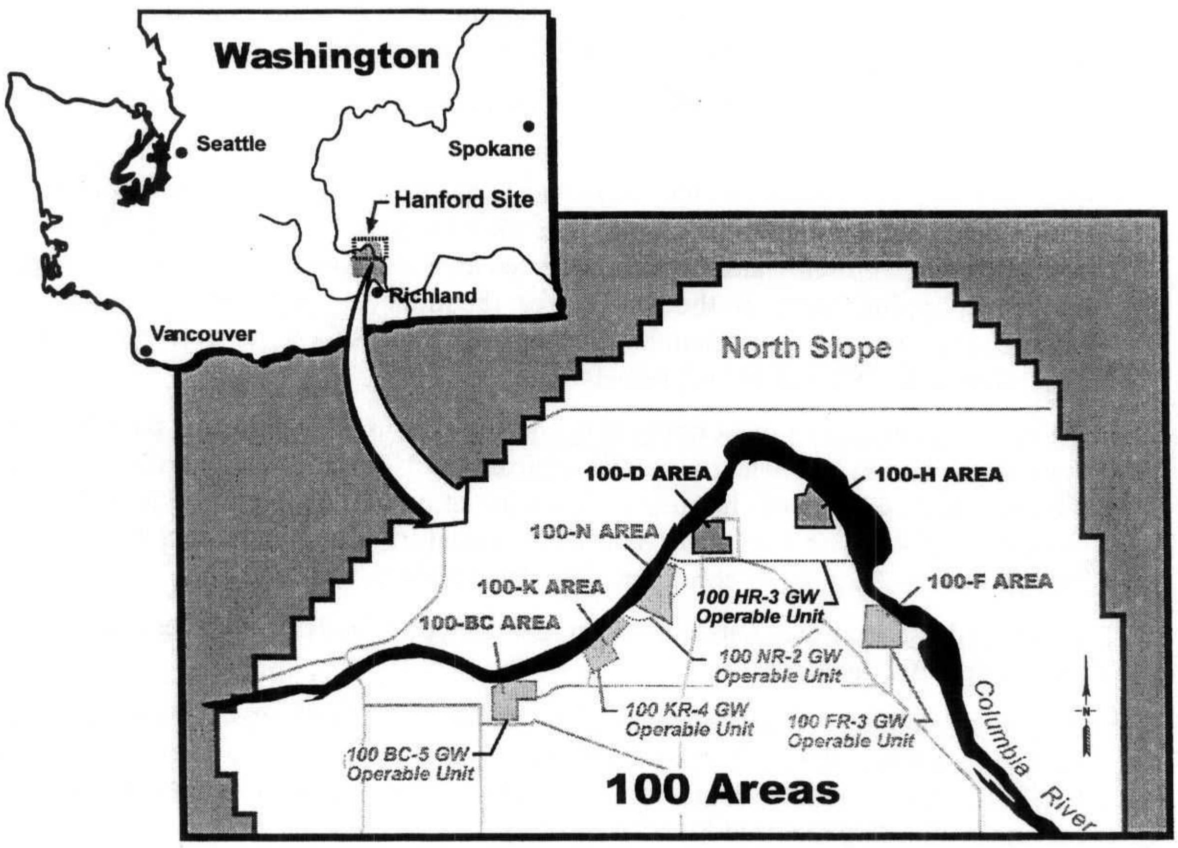


Figure 2-2. 100-HR-3 Operable Unit – 100-D Area Wells and Aquifer Sampling Tubes.

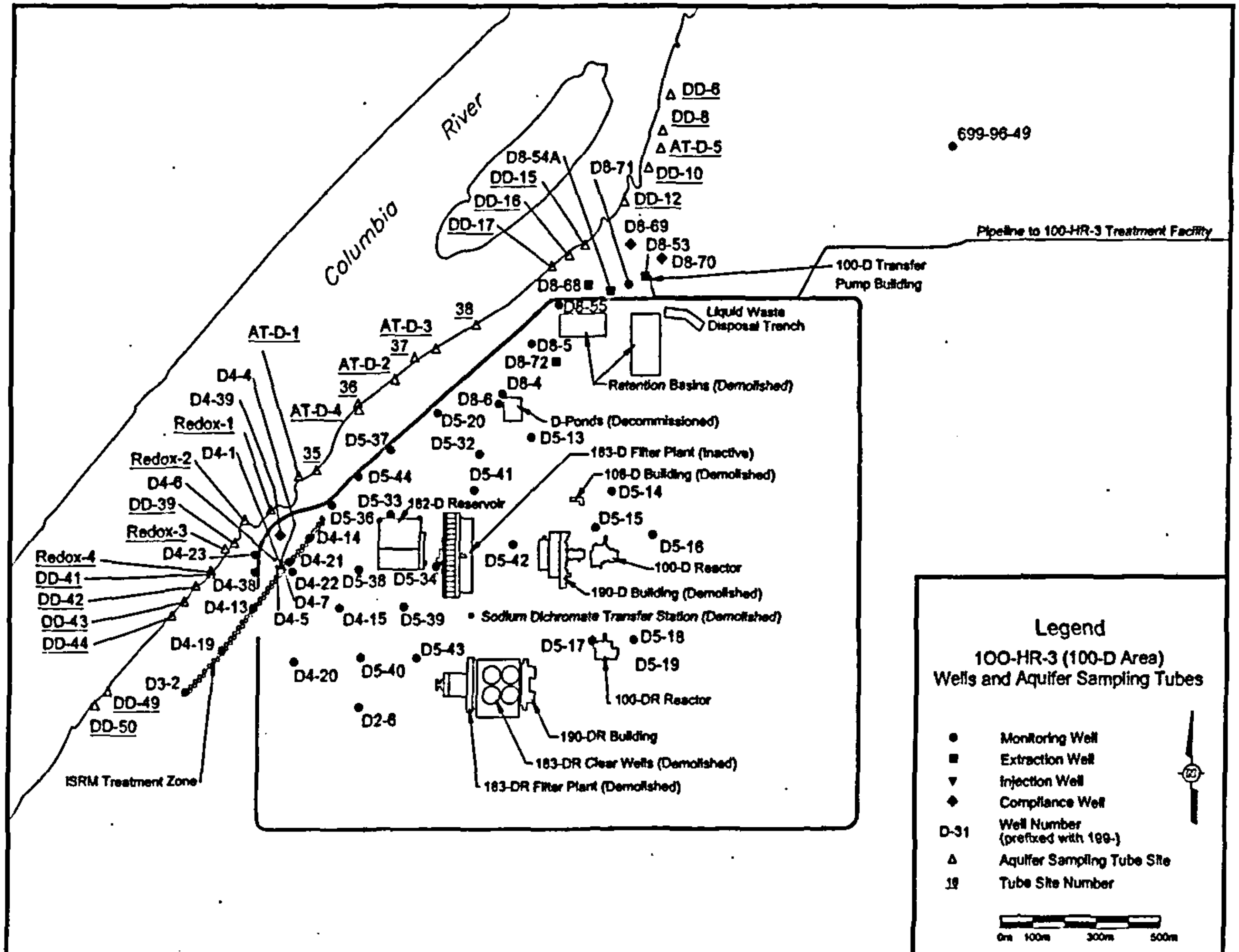


Figure 2-3. 100-HR-3 Operable Unit – 100-H Area Wells and Aquifer Sampling Tubes.

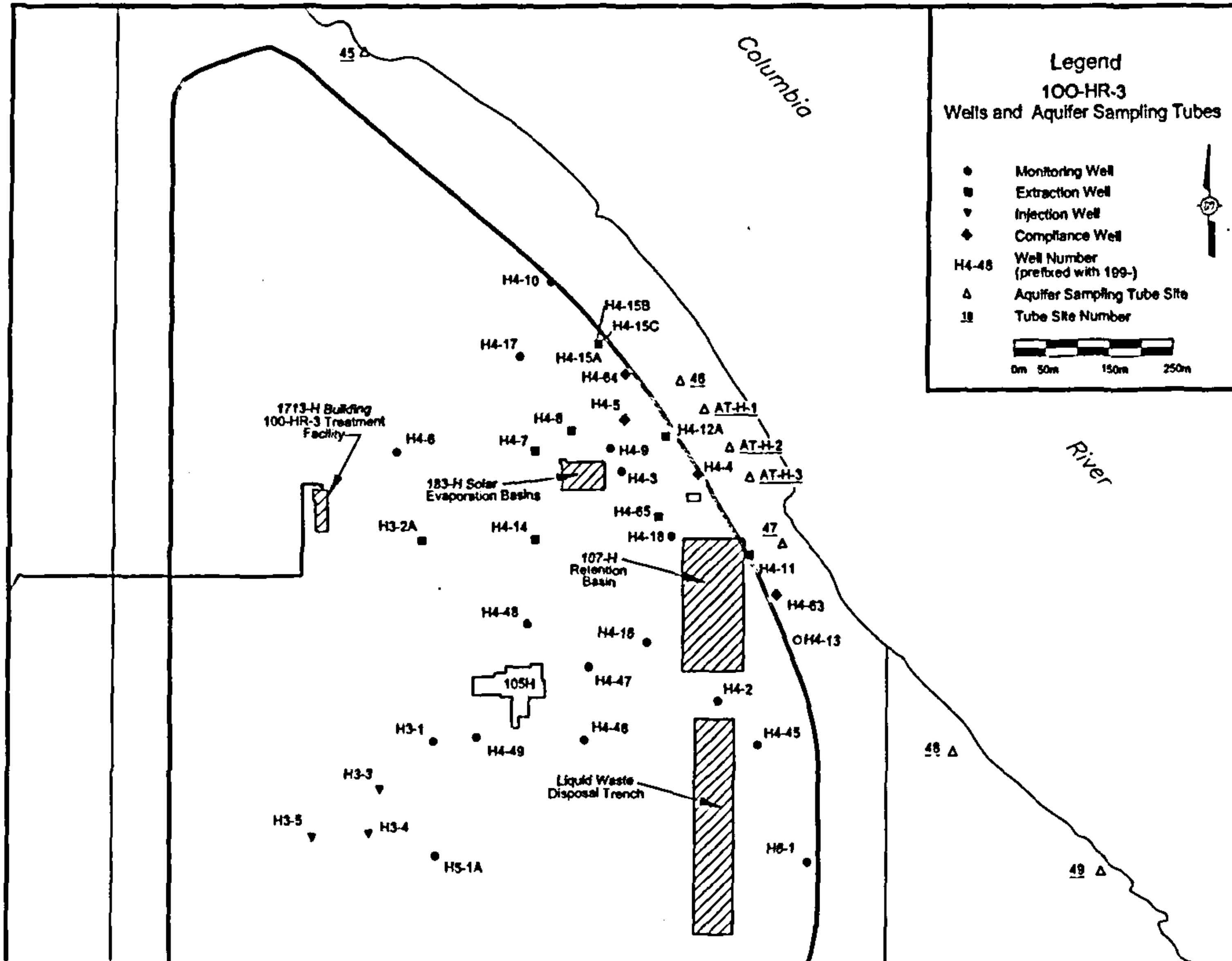


Figure 2-4. 100-HR-3 Operable Unit Pump-and-Treat System Schematic.

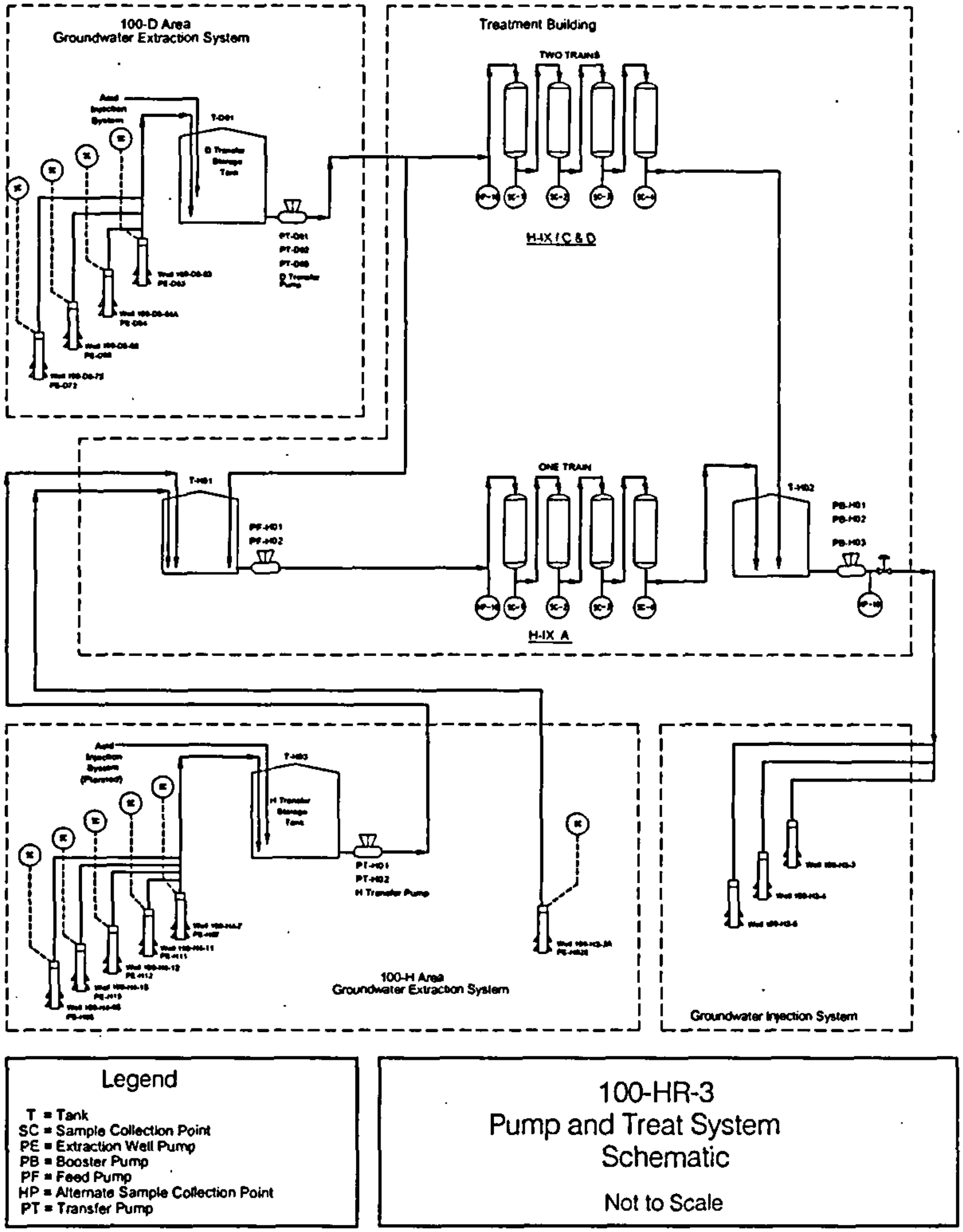


Figure 2-5. 100-HR-3 Pump-and-Treat Trends of Average Removal Efficiencies.

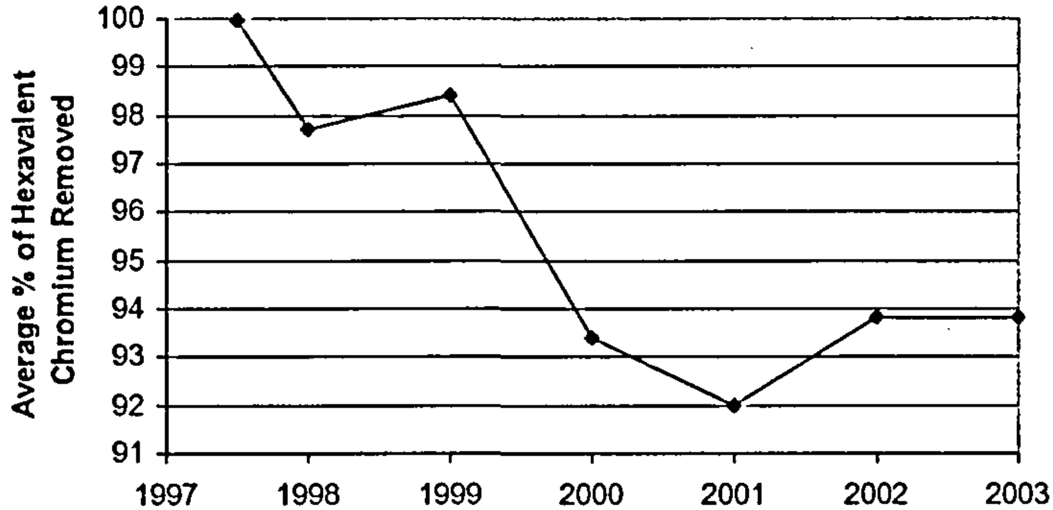
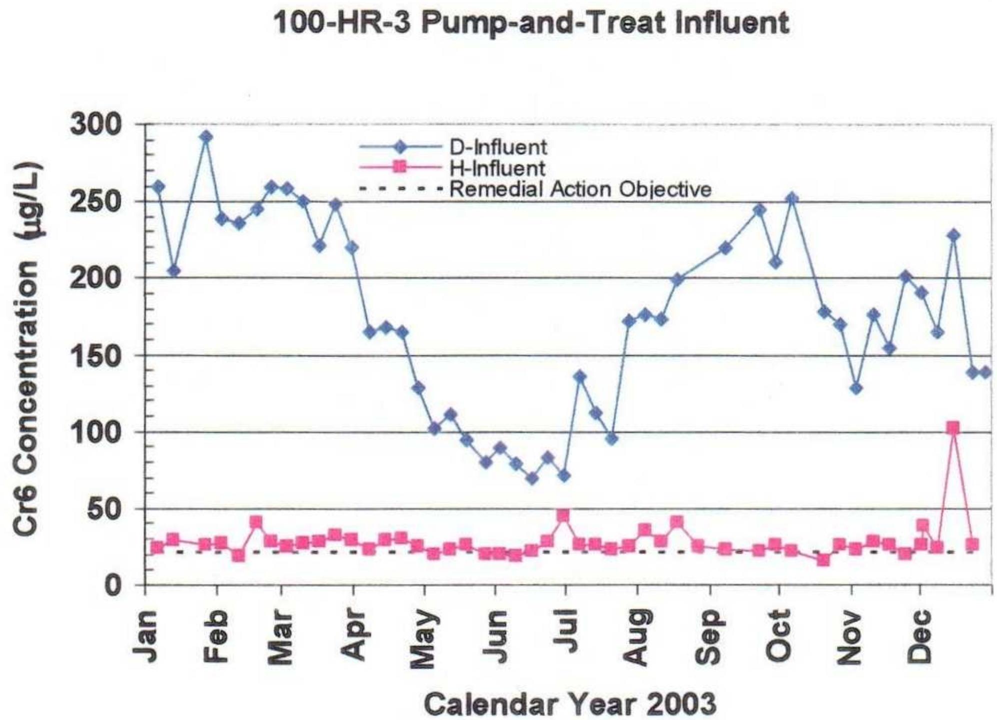


Figure 2-6. Calendar Year 2003 100-HR-3 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations.



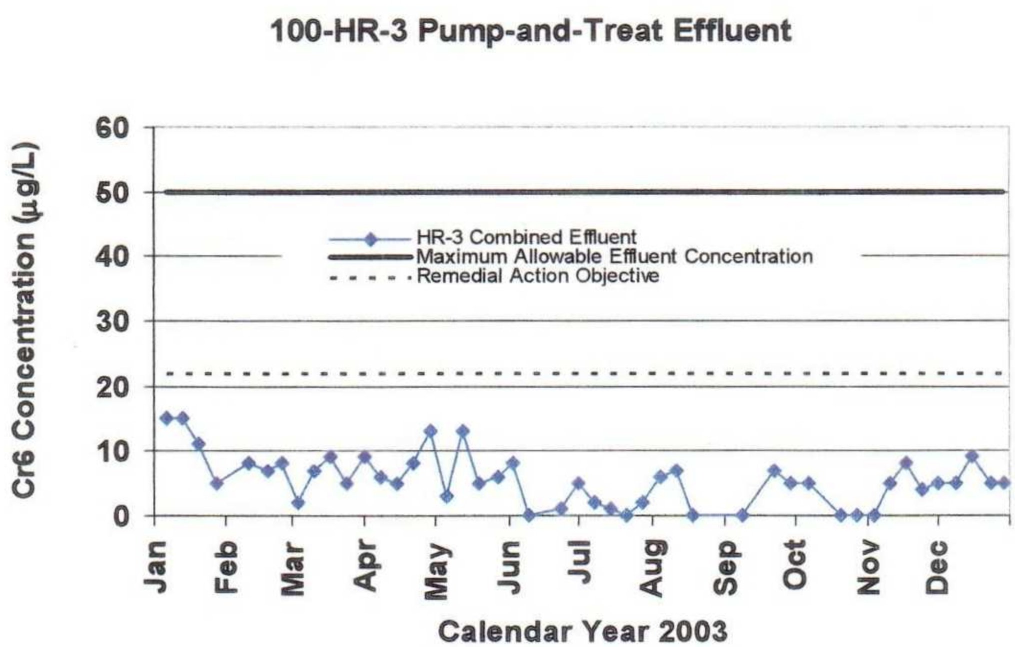
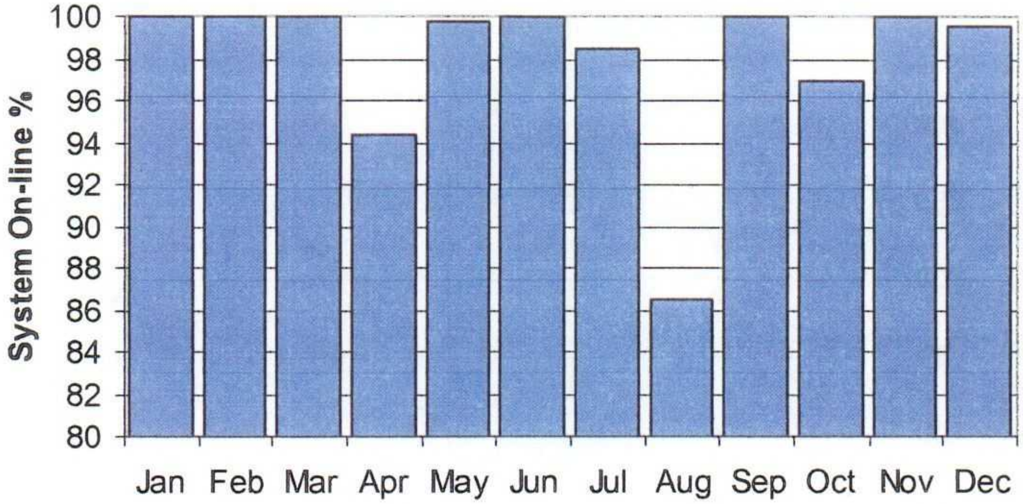
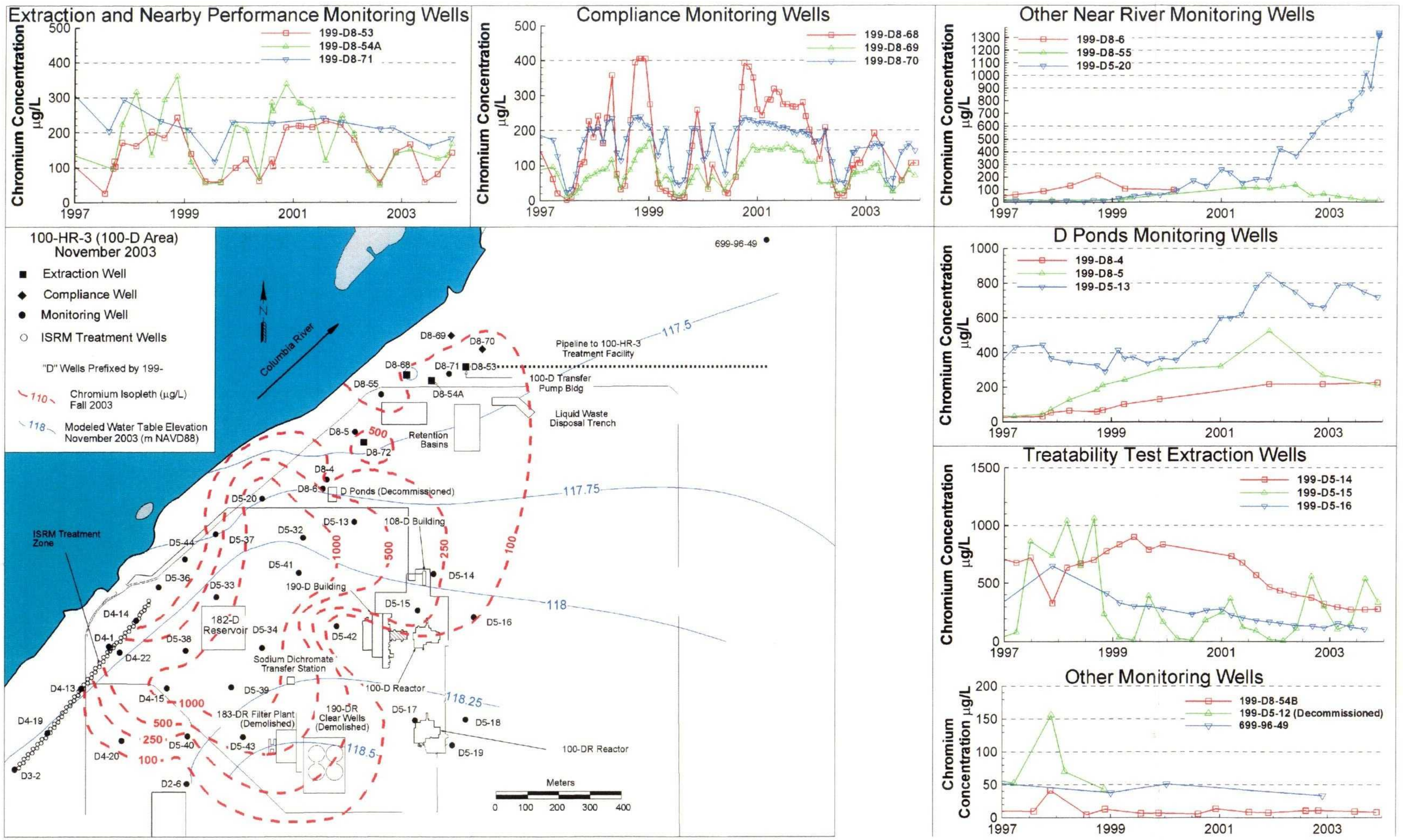


Figure 2-7. 100-HR-3 System Availability and On-Line Percentages for Calendar Year 2003.



April 12 to 16: Shut down for 45 hours due to expected power outage at 100-D for utilities update.
May 13: System shut down for 1.5 hours due to booster pump failure.
July 2: System shut down for 4 hours due to expected utilities outage and fuse changeout.
July 7: System shut down for 8 hours due to expected utilities power outage.
August 14: System shut down for 90.5 hours due to scheduled power outage.
October 21 to 22: System shut down for 24 hours to changeout transformer.
December 3: System shut down for 2.5 hours due to possible leak.
December 16: System shut down for 0.5 hours for scheduled maintenance.

Figure 2-8. 100-D Area Chromium Plume Map, Fall 2003.



3.0 100-KR-4 PUMP-AND-TREAT SYSTEM

The 100-KR-4 pump-and-treat facility is located along the Columbia River, several miles southwest of the 100-HR-3 OU (Figure 3-1). The 100-KR-4 OU includes the groundwater underlying the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 treatment system and injection/extraction well field are located northeast of the KE Reactor and adjacent to the 116-K-2 mile-long disposal trench. A map of wells and aquifer tube locations in the 100-K Area is presented in Figure 3-2. Appendix A provides a history of operations in the development of the 100-KR-4 pump-and-treat system.

The 100-KR-4 interim action is similar to the 100-HR-3 interim action in that the primary COC is hexavalent chromium. Interim action co-contaminants in the 100-KR-4 include tritium and strontium-90.

This section provides the annual performance report for 100-KR-4 for the reporting period of January 1 through December 31, 2003. Section 3.1 summarizes the activities pertaining to the 100-KR-4 pump-and-treat system and the source area remedial actions within the OU. Section 3.2 summarizes the treatment system performance, system operations, extraction well operations, and operational sampling. An evaluation of the aquifer response, including hydraulic monitoring, numerical modeling, and contaminant monitoring, is discussed in Section 3.3. Section 3.4 presents conclusions on the progress toward achieving each RAO and the performance criteria. Section 3.5 provides recommendations to change/enhance the 100-KR-4 OU pump-and-treat system. Cost information for the 100-KR-4 pump-and-treat system is presented separately in Section 5.0.

3.1 SUMMARY OF PUMP-AND-TREAT AND SOURCE OPERABLE UNIT ACTIVITIES

A summary of activities associated with the 100-KR-4 pump-and-treat system and source area activities that were completed in CY03 is outlined below:

- Well 199-K-126 was converted from a monitoring well to an extraction well in January 2003. This conversion was performed to supplement the capture of the northeastern portion of the chromium plume.
- Due to excessive sanding problems in well 199-K-112 that limited discharge rates, well 199-K-129 was constructed as a replacement extraction well on February 21, 2003. Pump equipment formerly in well 199-K-112 was transferred to well 199-K-129, and the well began operating on July 17, 2003.
- To help define and characterize the northeast extent of the chromium plume, well 199-K-130 was constructed as a monitoring/extraction well on February 14, 2003. The first sampling event for this well was conducted in March 2003.
- Six new aquifer tube installations along the 100-KR-4 shoreline were proposed for the fall of 2003. Permitting delays and severe weather delayed the start of field work until January 2004. Sampling results will be presented in the CY04 semi-annual technical memorandum.
- Effluent pipelines and contaminated soils associated with the 116-K-1 Crib and the 116-KE-4 retention basin were removed by the Environmental Restoration Contractor.

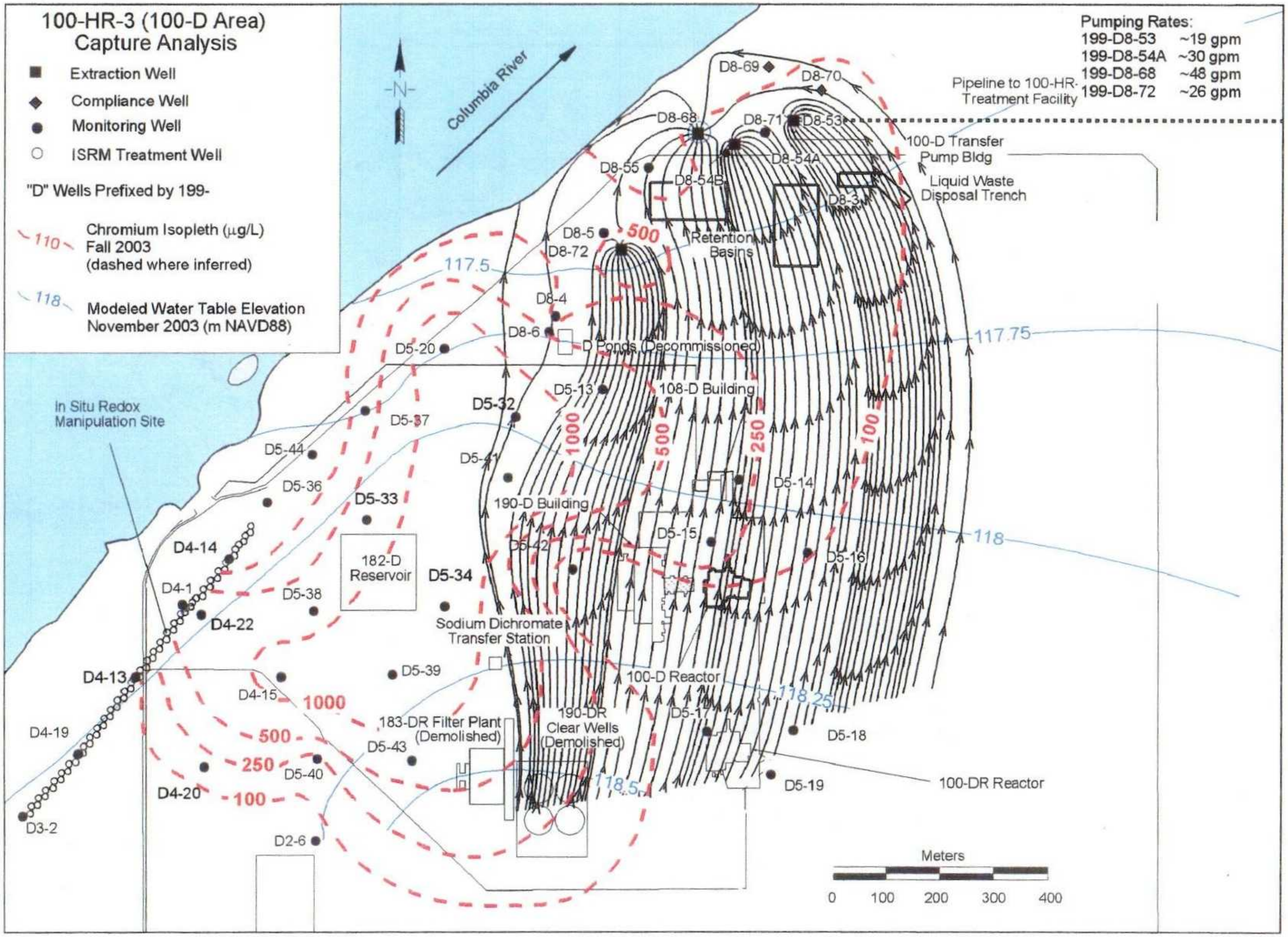


Figure 2-9. Estimated Steady-State Hydraulic Capture Zone Development by 100-HR-3 Operable Unit, 100-D Area Extraction Wells.

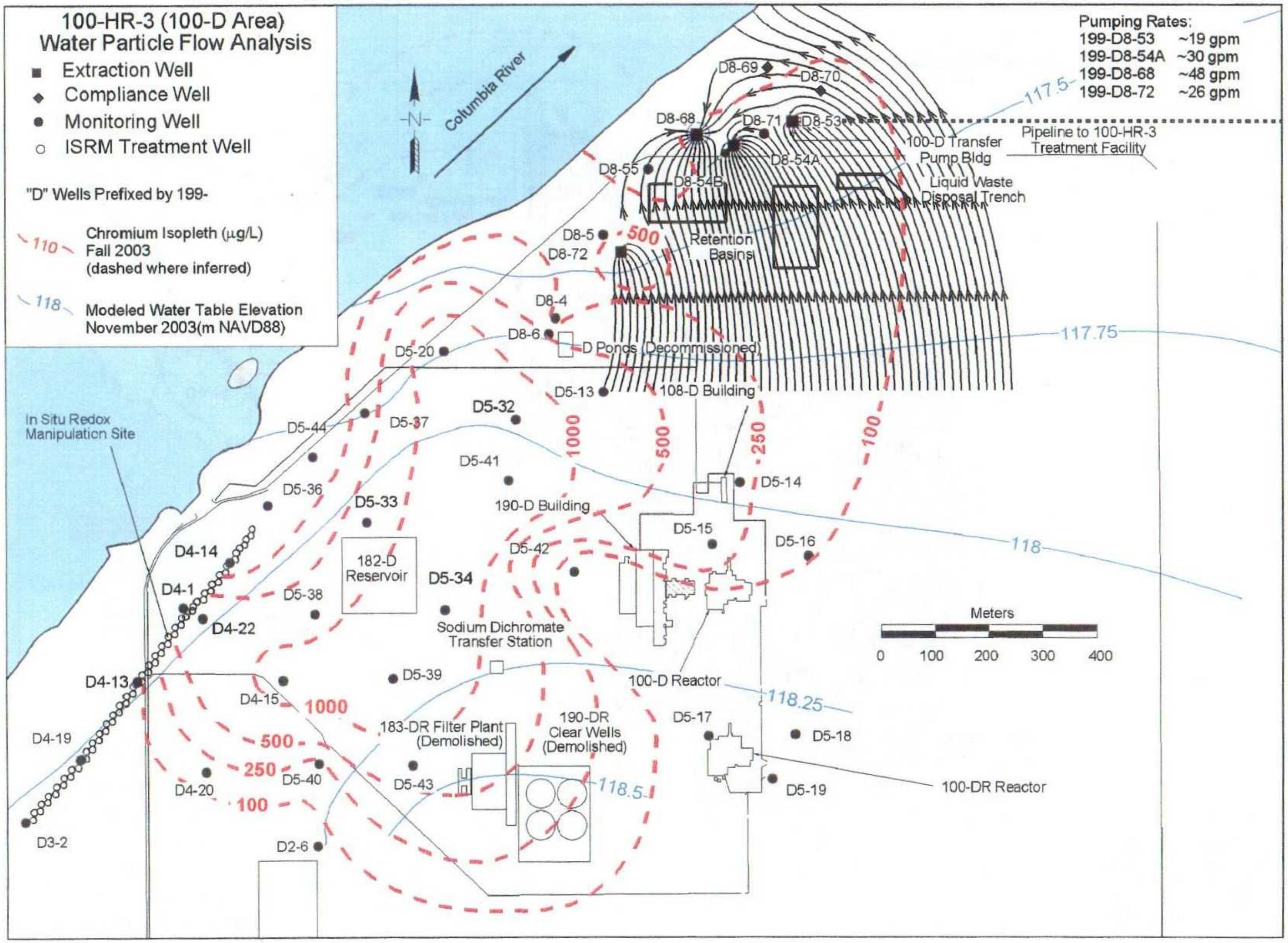
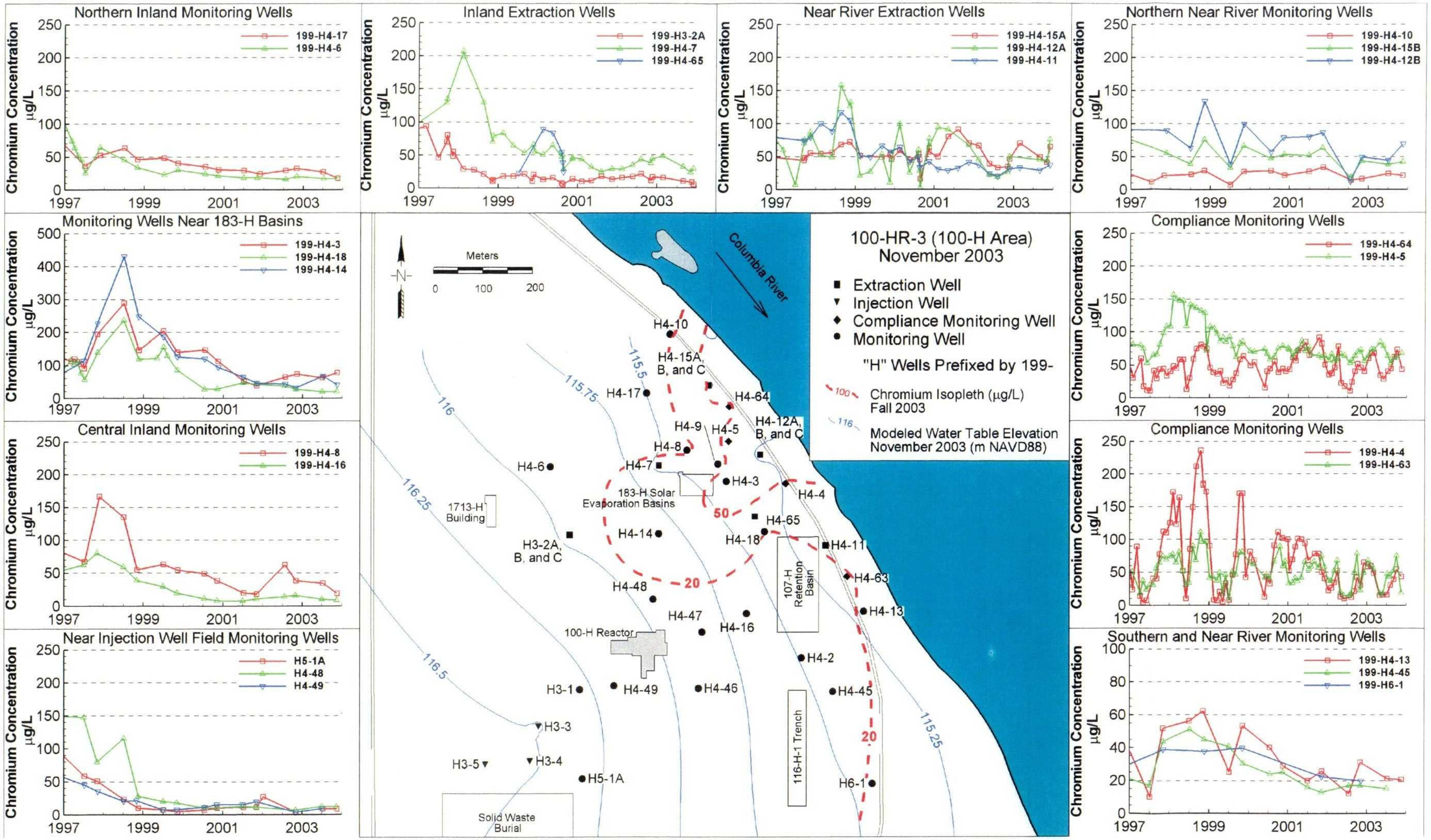


Figure 2-10. Evaluation of 100-HR-3 (100-D Area) Hydraulic Capture Using Water Particle Flow Analysis.

Figure 2-11. 100-H Area Chromium Plume, Fall 2003.



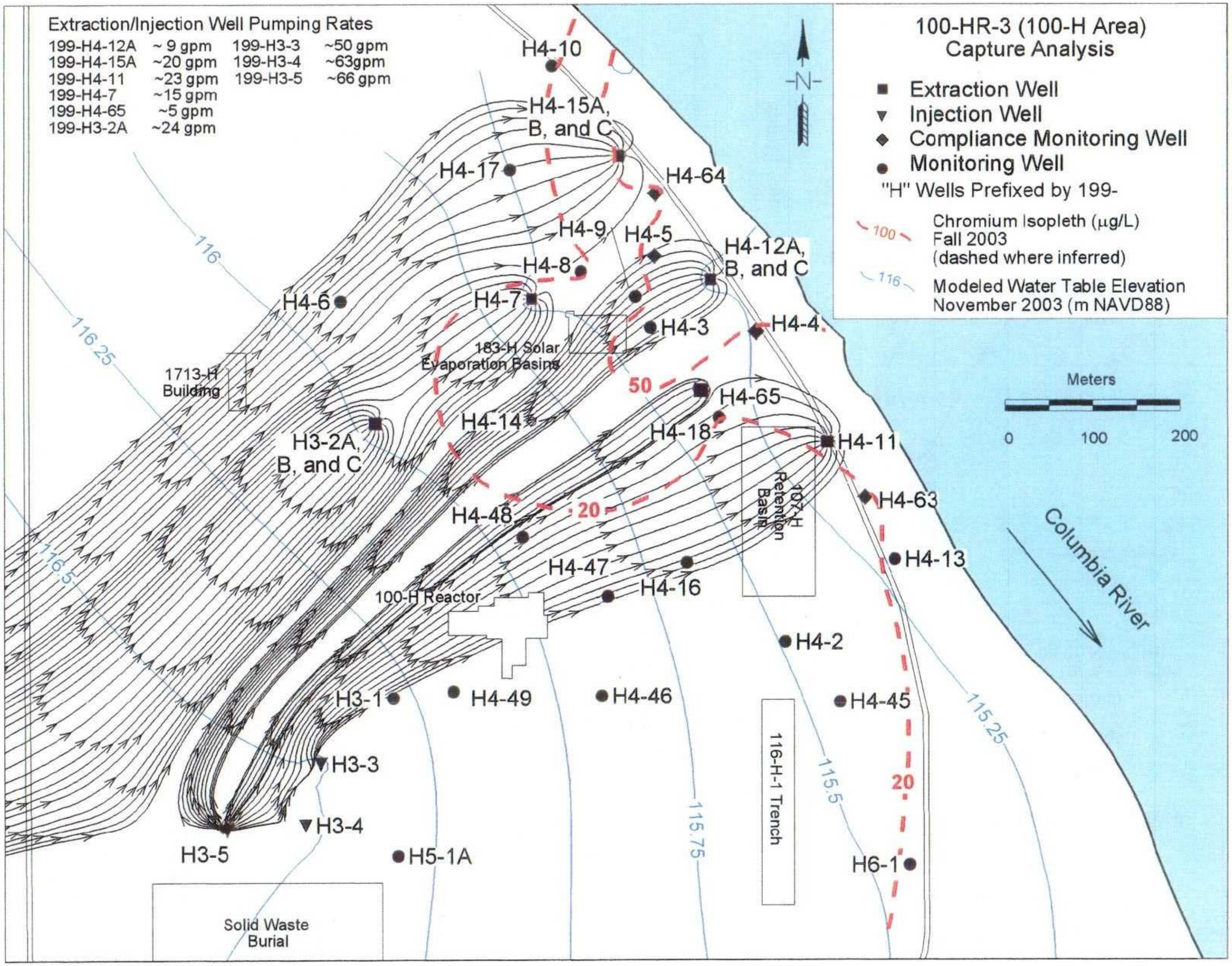


Figure 2-12. Estimated Steady-State Hydraulic Capture Zone Developed by 100-HR-3 Operable Unit, 100-H Area Extraction Wells.

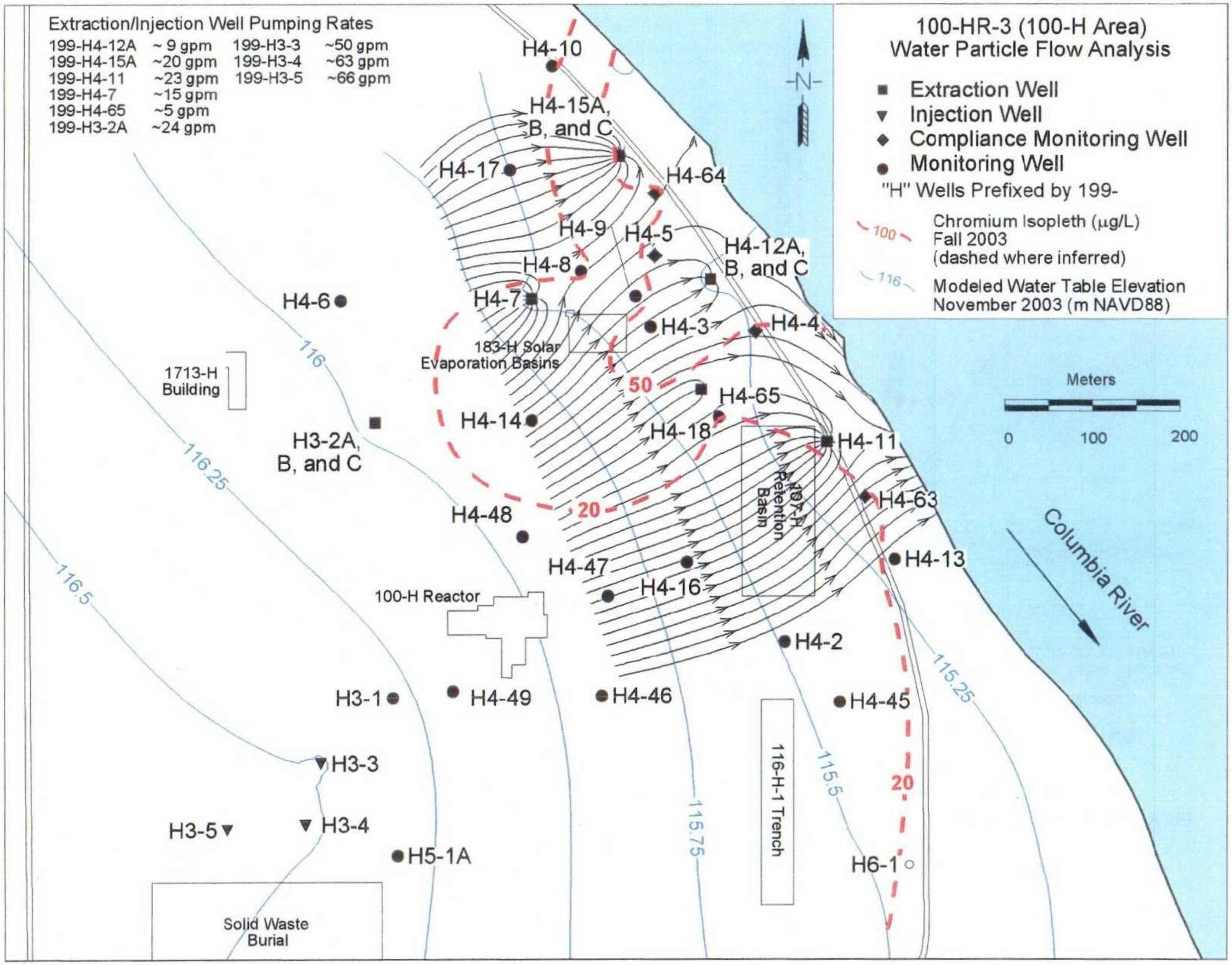
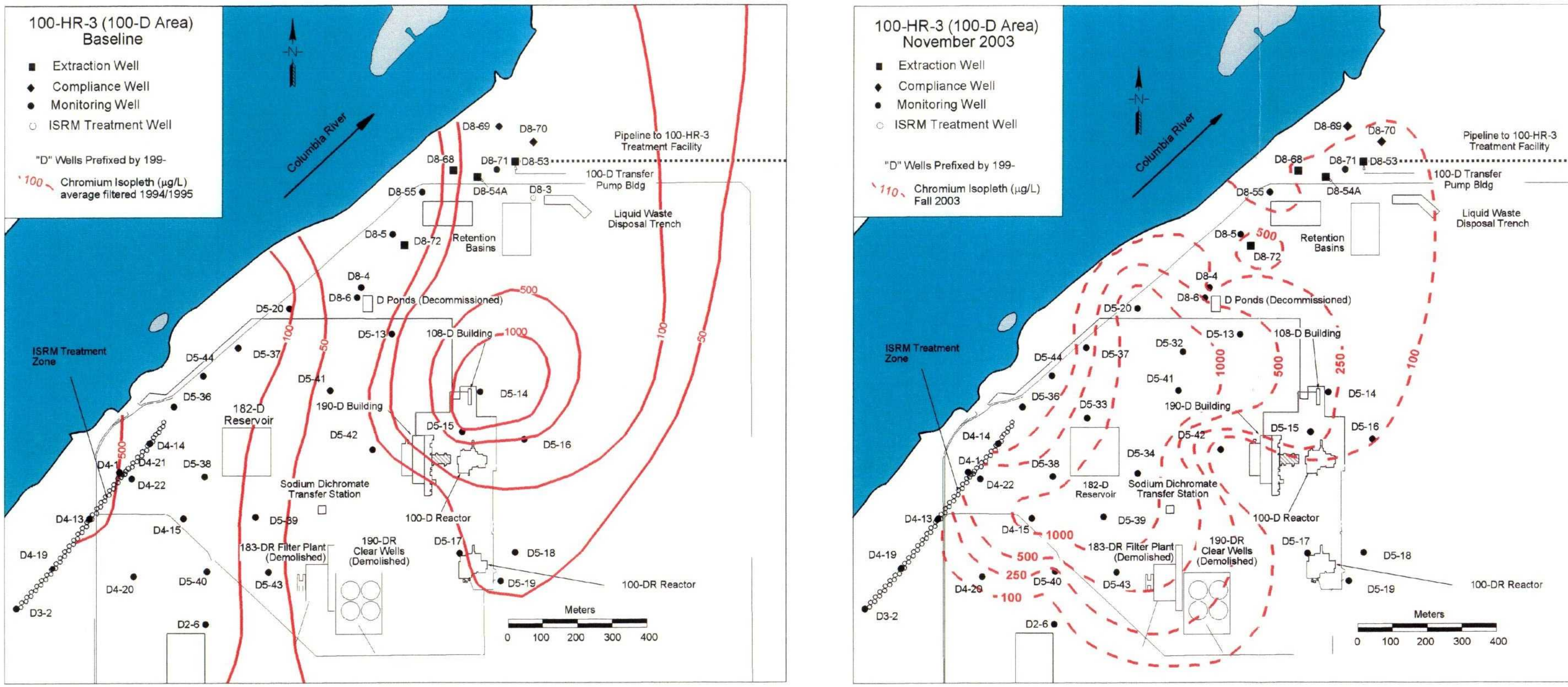


Figure 2-13. Evaluation of 100-HR-3 (100-H Area) Hydraulic Capture Using Water Particle Flow Analysis.

Figure 2-14. 100-D Operable Unit Chromium Plume Map, 1995 and 2003.



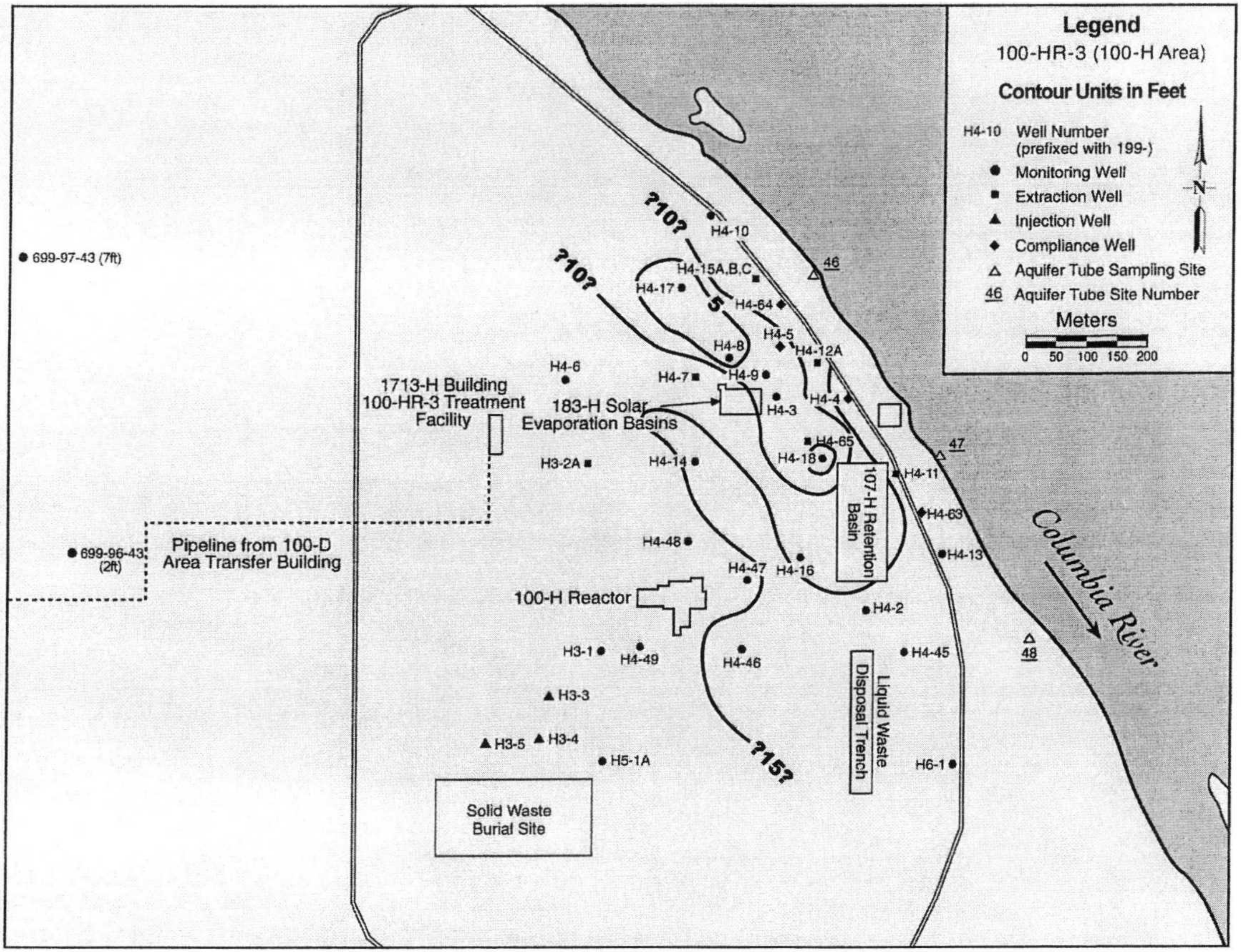


Figure 2-15. Saturated Thickness of Uppermost Aquifer Underlying the 100-H Area.

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Figure 2-16. 100-H Area Chromium Plume Map, 1995 and 2003.

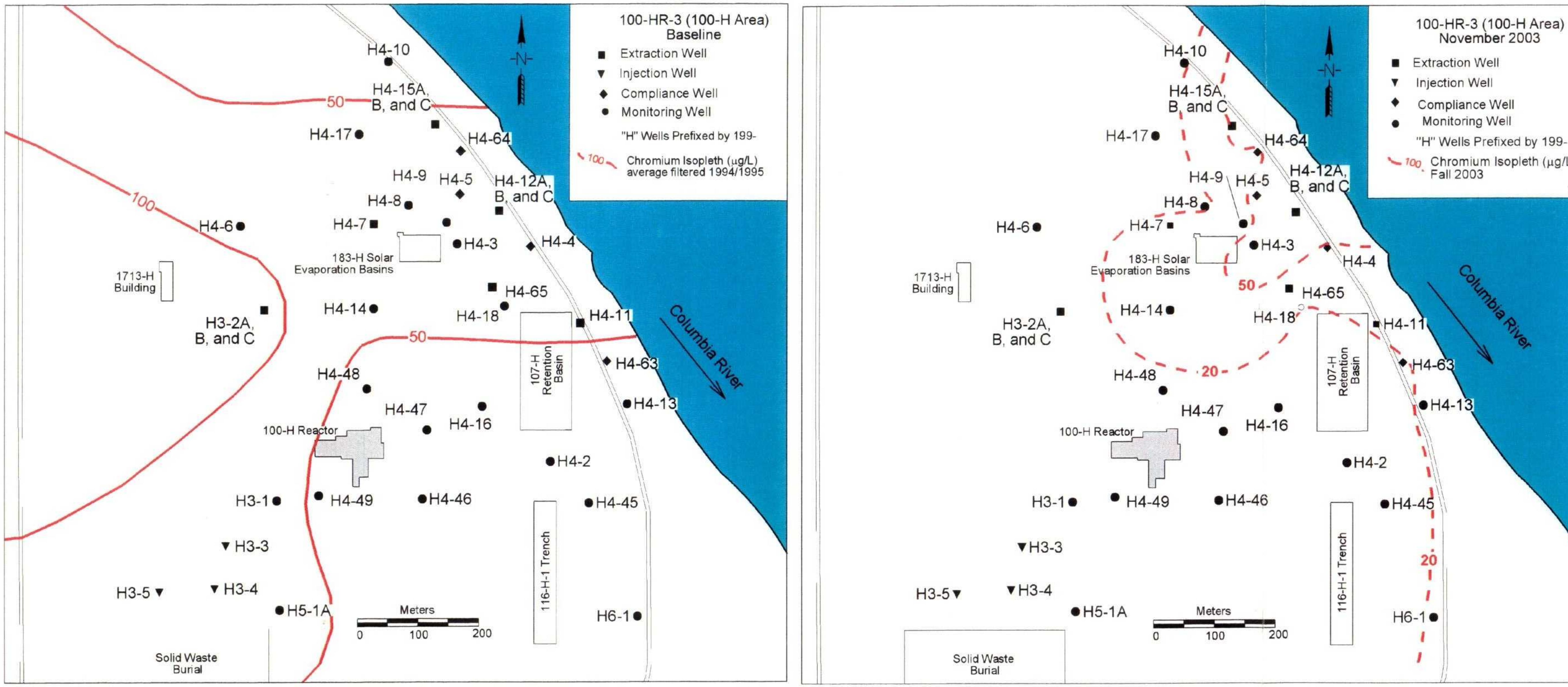


Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models. (2 sheets)

Well	Model Analysis, November 2003		Measured Water-Level Elevation Nov. 2003 (m)	Modeled Water-Level Elevation, Nov. 2003 (m)
	Extraction Rate (L/min)	Injection Rate (L/min)		
100-H Area				
199-H3-2A	91	—	115.91	115.89
199-H4-7	57	—	115.01	115.25
199-H4-11	87	—	114.80	115.06
199-H4-12A	34	—	114.59	115.20
199-H4-15A	76	—	115.31	115.22
199-H4-65	19	—	115.55	115.27
199-H3-3	—	190	116.43	116.53
199-H3-4	—	235	116.45	116.61
199-H3-5	—	250	116.66	116.70
199-H3-2B	—	—	115.91	115.94
199-H3-2C	—	—	115.91	115.94
199-H4-4	—	—	115.19	115.25
199-H4-5	—	—	115.29	115.31
199-H4-8	—	—	115.40	115.42
199-H4-10	—	—	114.16	115.39
199-H4-12B	—	—	115.19	115.24
199-H4-12C	—	—	115.18	115.24
199-H4-15B	—	—	115.20	115.26
199-H4-63	—	—	115.04	115.18
199-H4-64	—	—	115.27	115.27
199-H4-49	—	—	116.21	116.18
199-H5-1A	—	—	116.35	116.32
100-H river	—	—	115.17	115.17

Table 2-1. 100-HR-3 (100-H and 100-D Areas) Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models. (2 sheets)

Well	Model Analysis, November 2003		Measured Water-Level Elevation Nov. 2003 (m)	Modeled Water-Level Elevation, Nov. 2003 (m)
	Extraction Rate (L/min)	Injection Rate (L/min)		
100-D Area				
199-D8-53	72	—	116.61	117.26
199-D8-54A	114	—	116.53	117.17
199-D8-68	182	—	117.10	117.09
199-D8-72	98	—	125.60	117.28
199-D8-69	—	—	117.16	117.32
199-D8-70	—	—	117.18	117.36
199-D8-71	—	—	117.15	117.32
100-D river	—	—	117.60	117.80

3.0 100-KR-4 PUMP-AND-TREAT SYSTEM

The 100-KR-4 pump-and-treat facility is located along the Columbia River, several miles southwest of the 100-HR-3 OU (Figure 3-1). The 100-KR-4 OU includes the groundwater underlying the 100-KR-1 and 100-KR-2 source OUs. The 100-KR-4 treatment system and injection/extraction well field are located northeast of the KE Reactor and adjacent to the 116-K-2 mile-long disposal trench. A map of wells and aquifer tube locations in the 100-K Area is presented in Figure 3-2. Appendix A provides a history of operations in the development of the 100-KR-4 pump-and-treat system.

The 100-KR-4 interim action is similar to the 100-HR-3 interim action in that the primary COC is hexavalent chromium. Interim action co-contaminants in the 100-KR-4 include tritium and strontium-90.

This section provides the annual performance report for 100-KR-4 for the reporting period of January 1 through December 31, 2003. Section 3.1 summarizes the activities pertaining to the 100-KR-4 pump-and-treat system and the source area remedial actions within the OU. Section 3.2 summarizes the treatment system performance, system operations, extraction well operations, and operational sampling. An evaluation of the aquifer response, including hydraulic monitoring, numerical modeling, and contaminant monitoring, is discussed in Section 3.3. Section 3.4 presents conclusions on the progress toward achieving each RAO and the performance criteria. Section 3.5 provides recommendations to change/enhance the 100-KR-4 OU pump-and-treat system. Cost information for the 100-KR-4 pump-and-treat system is presented separately in Section 5.0.

3.1 SUMMARY OF PUMP-AND-TREAT AND SOURCE OPERABLE UNIT ACTIVITIES

A summary of activities associated with the 100-KR-4 pump-and-treat system and source area activities that were completed in CY03 is outlined below:

- Well 199-K-126 was converted from a monitoring well to an extraction well in January 2003. This conversion was performed to supplement the capture of the northeastern portion of the chromium plume.
- Due to excessive sanding problems in well 199-K-112 that limited discharge rates, well 199-K-129 was constructed as a replacement extraction well on February 21, 2003. Pump equipment formerly in well 199-K-112 was transferred to well 199-K-129, and the well began operating on July 17, 2003.
- To help define and characterize the northeast extent of the chromium plume, well 199-K-130 was constructed as a monitoring/extraction well on February 14, 2003. The first sampling event for this well was conducted in March 2003.
- Six new aquifer tube installations along the 100-KR-4 shoreline were proposed for the fall of 2003. Permitting delays and severe weather delayed the start of field work until January 2004. Sampling results will be presented in the CY04 semi-annual technical memorandum.
- Effluent pipelines and contaminated soils associated with the 116-K-1 Crib and the 116-KE-4 retention basin were removed by the Environmental Restoration Contractor.

3.2 100-KR-4 TREATMENT SYSTEM PERFORMANCE

This section describes the 100-KR-4 pump-and-treat system operations and sampling activities that occurred in CY03. Specific details include changes to the system configuration, system availability, mass of contaminants removed during operations, contaminant removal efficiencies, quantity and quality of extracted and disposed groundwater, waste generation, and contaminant trends. A detailed discussion of this information is presented in the associated appendices as called out in the text.

As discussed above, extraction well 199-K-112 was replaced with new extraction well 199-K-129, and existing monitoring well 199-K-126 was converted to an extraction well. The current 100-KR-4 pump-and-treat system configuration consists of nine extraction wells and five injection wells. Modification to the pump-and-treat process facility involved the addition of a second transfer pump at the K-2 Transfer Building to increase throughput and system reliability. The impeller for pump PT-K01 at the K-1 Transfer Building was changed out to increase the pump's capacity. The treatment facility continues to consist of 3 skids with 12 treatment vessels. Figure 3-3 presents the current system schematic of the pump-and-treat system for CY03.

A summary of operational parameters and total system performance for CY03 is presented in the table below:

Total processed groundwater:	
Total amount of groundwater treated (since October 1997 startup) (billion L)	2.21
Total amount of groundwater treated during CY03 (million L)	517.6
Mass of hexavalent chromium removed:	
Total amount of hexavalent chromium removed (since October 1997 startup) (kg)	220.7
Total amount of hexavalent chromium removed in CY03 (kg)	36.7
Summary of operational parameters:	
Removal efficiency (% by mass)	95.2%
Waste generation (m^3)	96.6
Regenerated resin installed (m^3)	52.1
New resin installed (m^3)	43.0
Number of resin changeouts	42
Summary of system availability:	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	142
Planned operations (hours)	8618
Unscheduled downtime (hours)	55
Total time on-line (hours)	8,563
Total availability (%)	97.7
Scheduled system availability (%)	99.3

Key operational and system highlights for CY03 are as follows:

- The 95.2% removal efficiency [(influent - effluent)/influent] for CY03 is the same as reported for CY02 (Figure 3-4).
- The average 100-KR-4 influent hexavalent chromium concentration of 75.1 µg/L was lower than the CY02 average of 84 µg/L.
- The average effluent hexavalent chromium concentration of 3.6 µg/L for CY03 was comparable to the 4 µg/L in CY02. Trend plots of CY03 influent and effluent concentrations are presented in Figure 3-5.
- The maximum hexavalent chromium concentration in the effluent was 27 µg/L.
- Scheduled system availability for CY03 was 99.3% (total possible run-time - unscheduled downtime)/total possible run-time), which was higher than the 98.3% reported in CY02. The total availability was 97.6% (total possible run-time - scheduled and unscheduled downtime)/total possible run-time). This is a slight increase from the on-line availability of 94.3% reported for CY02. Figure 3-6 presents the monthly on-line percentages and events impacting system availability for the reporting period.
- During CY03, 42 ion-exchange vessels were changed out, generating 96.6 m^3 of spent resin. This amount is significantly higher than the 58 m^3 removed in CY02 and can be attributed to the larger amount of water processed during the current reporting period. As with the 100-HR-3 pump-and-treat system, resin changeouts were performed to maximize operating time and to limit the volume of material requiring regeneration or disposal.

Well	Recommended Flow Rate (gpm/liters)	Yearly Average Flow Rate (gpm/liters)	Total Flow Hours in CY03	Total Run Time (%)[c]
199-K-112A/ 199-K-129[a]	25/94.6	21.7/82.1	7,328.5	83.6
199-K-113A	25/94.6	13.8/52.2	8,378.5	95.6
199-K-115A	25/94.6	42.8/162.0	8,522	97.2
199-K-116A	40/151.4	40.2/152.2	8,420	96.1
199-K-119A	30/113.6	30.0/113.6	8,521.5	97.2
199-K-120A	30/113.6	31.3/118.5	8,522.5	97.2
199-K-125A	30/113.6	33.6/127.2	8,483.5	96.8
199-K-127	40/151.4	35.7/135.1	8,523.5	93.0
199-K-126	14.3[b]/54.1	13.8/52.2	8,154.5	97.3

[a] Extraction well 199-K-112A was replaced with well 199-K-129, which began operating as an extraction well on July 10, 2003.
[b] Recommended flow rate based upon drawdown analysis.
[c] (Total flow hours in CY03)/total hours in CY03 x 100%.

The table above presents information associated with the pumping flow rates and total run-time (total flow hours/total possible run-time) for extraction wells at the 100-KR-4 pump-and-treat system. Except where noted, the recommended flow rates are based upon updated numerical modeling results that were prepared to support the *Comprehensive Environmental Response, Compensation, and Recovery Act of 1980* (CERCLA) 5-year review design modification. The yearly average flow rates are calculated from actual totalized volumes divided by the total hours in a year.

A comparison of the extraction wells presented above shows that wells 199-K-115A, 199-K-120A, and 199-K-125A were pumped at greater flow rates than recommended. These wells were able to sustain higher yields during the reporting period and were therefore used to offset lower flow rates from wells 199-K-112A, 199-K-113A, and 199-K-127. Ongoing problems of excessive sanding at well 199-K-112A limited the well's ability to reach the recommended flow rates. This problem was addressed by constructing replacement well 199-K-129.

The lower-than-recommended flow rates at wells 199-K-113A and 199-K-127 may be attributed to fluctuations in river levels throughout the year, which resulted in a thinner aquifer and less available drawdown for these wells. During the year, all wells were subject to downtime because of area power-grid outages, equipment failures or maintenance, and construction activities. This downtime is reflected in the yearly average flow rate calculations and the total run-time percentages for each extraction well.

Well 199-K-126 was converted to an extraction well at the end of 2002 and was brought on-line January 13, 2003. This conversion was performed to extend the capture of the northern portion of the chromium plume. A modeling analysis performed in CY02 indicated that capture would be sustained at a pumping rate of approximately 45.4 L/min (12 gpm). Pumping evaluations conducted after well 199-K-126 was brought on-line showed that average yearly pumping at 52.2 L/min (13.8 gpm) could be sustained.

Historical presentation of operational parameters, total system performance, and extraction well chromium concentration and extraction rates can be found in Appendix B.

3.3 AQUIFER RESPONSE IN THE 100-K AREA

This section describes the general hydrogeologic conditions in the 100-K Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

3.3.1 Hydrogeologic Conditions at the 100-K Area

The hydrogeologic conditions at the 100-K Area are as follows:

- The most prevalent groundwater flow direction is northwest, as shown in Figure 3-7. During spring months, the river elevation is generally higher because of increased run-off and to provide more irrigation water and aid fish migration. This flow reversal from northwest to southeast is clearly shown in Figure C-7 of Appendix C, where the May and June 2003 river elevations are higher than near-river wells.
- The average November 2003 river-stage elevation was 115.38 m (378.54 ft) compared to the average 1991-2003 November river-stage elevation of 115.19 m (377.92 ft).

- The November 2003 hydraulic gradient ranged from 0.002 to 0.017 toward the northwest based on the groundwater surface elevation contours shown in Figure 3-7.
- The estimated groundwater flow velocity range at the 100-K Area was 0.03 to 2.0 m/day (0.98 to 6.56 ft/day) based on a hydraulic conductivity range of 2.0 to 16.5 m/day (6.56 to 54.13 ft/day), porosity of 0.2, and a gradient of 0.002 to 0.17. The maximum hydraulic conductivity and porosity were estimated to be the same as the Ringold Formation at the 100-D Area. The low range of hydraulic conductivities represented the area of the injection wells where there has been a substantial buildup in the wells.
- The average 2003 extraction well pumping rates ranged from 166.5 L/min (44 gpm) in well 199-K-115 to 54.5 L/min (14.4 gpm) in well 199-K-113A. This compares to a range of 153.3 L/min (40.5 gpm) to 53.9 L/min (14.0 gpm) in 2002.

3.3.2 Numerical Modeling

The following is a summary of the numerical modeling results supporting the 100-KR-4 pump-and-treat operations:

- The original target hexavalent chromium pump-and-treat plume from the 116-K-2 Trench (north to the Columbia River) is within the capture zone of the existing extraction well network, as shown in Figures 3-8 and 3-9.
- The conversion of compliance well 199-K-126 to an extraction well in January 2003 has extended the capture zone further downstream to include an area where monitoring results have confirmed that the chromium plume has moved.
- A list of the modeled water table elevations and average modeled flow rates is presented in Table 3-1.
- A measured drawdown/buildup analysis was not necessary to support the 2003 modeled results because of the strong similarity between 2002 and 2003 extraction well pumping rates, river stage, and hydraulic gradient. This analysis may be conducted in future years if conditions vary significantly.

3.3.3 Contaminant Monitoring

This section summarizes and interprets the CERCLA analytical results obtained from groundwater monitoring wells supporting the 100-K Area pump-and-treat remedial action. Section 3.3.3.1 includes a discussion about chromium monitoring results. Section 3.3.3.2 includes a discussion about monitoring results for remedial action co-contaminants strontium-90 and tritium. Nitrate and carbon-14 are constituents of interest. Fall samples were collected from mid-October through early December 2003.

The highlights for CY03 are listed below:

- Chromium concentrations decreased in all extraction wells and decreased more than 20% in four extraction wells; however, the concentrations remained above the RAO of 22 μg/L in all extraction wells. The maximum chromium concentration in an extraction well was 119 μg/L in well 119-K-116A, which also had the highest chromium concentration in 2002 (133 μg/L).

- The farthest downstream monitoring well, 199-K-130, was characterized by an average chromium concentration of 81.4 µg/L in October 2003. This well became operational as a monitoring well in March 2003.
- The maximum strontium-90 concentration in a pump-and-treat area well was 20.2 pCi/L in well 199-K-114A in October 2003.
- Tritium was above the 20,000 pCi/L MCL in three pump-and-treat area wells, with a maximum concentration of 45,850 pCi/L in compliance well 199-K-18. Tritium concentrations decreased by more than 20% in the other three wells characterized by tritium above the 20,000 pCi/L MCL.

3.3.3.1 Chromium Monitoring Results

Chromium concentrations are monitored in nine extraction wells, four compliance wells, and eight monitoring wells in the pump-and-treat operational area. Additional CERCLA monitoring wells outside the area affected by pump-and-treat operations also are monitored for chromium.

The October 2003 100-K Area chromium plume and associated historical trends are displayed in Figure 3-7. The table below compares the 2002 versus 2003 chromium analytical results for extraction wells, compliance wells, and selected monitoring wells impacted by pump-and-treat operations. Results shown are filtered hexavalent chromium, unless indicated otherwise.

Well	Type	Fall 2002 Cr (µg/L)	Fall 2003 Cr (µg/L)	Percent Change
199-K-112A[a]	Extraction	64	[a]	[a]
199-K-113A	Extraction	57	44	-23
199-K-114A	Compliance	89	111	+25
199-K-115A	Extraction	96	52	-46
199-K-116A	Extraction	133	119	-11
199-K-117A	Compliance	12	10.5	-12
199-K-119A	Extraction	64	45	-30
199-K-120A	Extraction	78	72	-8
199-K-125A	Extraction	55	41	-25
199-K-126	Extraction[b]	110[d]	98	-11
199-K-127	Extraction	71	61	-14
199-K-129	Extraction	[c]	63	NA
199-K-18	Compliance	113	131	+16
199-K-19	Monitoring	84	78	-7
199-K-20	Compliance	29	20	-31
199-K-111A	Monitoring	35.4[f]	39[f]	+10
199-K-32A	Monitoring	15.5[f]	12.4[f]	-20
199-K-32B[e]	Monitoring	12.1[f]	7.8[d,f]	-36
199-K-37	Monitoring	70	73	+4
199-K-22	Monitoring	148	139	-6

Well	Type	Fall 2002 Cr (μg/L)	Fall 2003 Cr (μg/L)	Percent Change
199-K-130	Monitoring	[c]	81.4[d]	NA
699-78-62	Monitoring	[c]	36.4[f]	NA

[a] Extraction well until May 2003; replaced by well 199-K-129.
[b] Well 199-K-126 converted to extraction well in January 2003.
[c] Not sampled during 2002.
[d] Averaged result.
[e] Monitors the confined aquifer.
[f] Filtered total chromium.
NA = not applicable

Chromium concentrations decreased from fall 2002 to fall 2003 in eight of nine extraction wells and decreased 20% or more in six extraction wells. Chromium concentrations increased in three compliance wells to a maximum of 25% in well 199-K-114A, and decreased by 31% in compliance well 199-K-20. Chromium concentrations in the monitoring wells were mostly stable (±20% of the fall 2002 values), except in wells 199-K-32A and 199-K-32B where values decreased by 20% and 36%, respectively. Well 199-K-32B monitors the confined aquifer.

Two aquifer tube sites downgradient of the K Reactors were sampled during December 2003. The sites are upriver from the 116-K-2 Trench area and outside the influence of the 100-K pump-and-treat system. The chromium results (both nondetects) were not used in generating the 100-K chromium plume map. A summary of CY03 aquifer sampling tube results is presented in Appendix E.

3.3.3.2 Co-Contaminant Monitoring Results

Strontium-90 and tritium are 100-KR-4 pump-and-treat co-contaminants, as listed in the 100-KR-4 ROD (EPA et al. 1996). Nitrate and carbon-14 are 100-K Area contaminants of interest that also are monitored as part of the CERCLA sampling program. The co-contaminant monitoring results are further described below:

- Strontium-90: Nine extraction wells, five compliance wells, and one monitoring well were monitored for strontium-90. One compliance well (199-K-114A) and two extraction wells (199-K-113A and 199-K-115A) were characterized by strontium-90 above the 8 ρCi/L MCL. The maximum 2003 strontium-90 concentration was 20.2 ρCi/L in compliance well 199-K-114A. The maximum change was 50% in extraction well 199-K-127; however, the strontium-90 concentration increased to only 3.0 ρCi/L in this well. The fall 2002 versus fall 2003 results for selected wells are summarized in the table below:

Well	Type	Fall 2002 Sr-90 (ρCi/L)[c]	Fall 2003 Sr-90 (ρCi/L)[c]	Percent Change[d]
199-K-18	Compliance	-0.1(U) (±0.37)	0.2(U) (±0.21)	NA
199-K-20	Compliance	8.4 (±2)	6.4 (±1.1)	-24
119-K-113A	Extraction	10.9 (±3.1)	11.5 (±2.8)	+6
199-K-114A	Compliance	17.5 (±3.9)	20.2 (±3.1)	+15
199-K-115A	Extraction	8.3 (±2)	8.8 (±2)	+5

Well	Type	Fall 2002 Sr-90 (pCi/L)[c]	Fall 2003 Sr-90 (pCi/L)[c]	Percent Change[d]
199-K-116A	Extraction	5.6[b] (±1.7)	5.6 (±1.1)	-1
199-K-117A	Compliance	1.6 (±0.6)	2.2[b] (±0.49)	+42
199-K-120A	Extraction	2.2 (±0.7)	1.4 (±0.5)	-37
199-K-127	Extraction	2.0 (±0.5)	3.0 (±1.6)	+50
199-K-130	Monitoring	[a]	-0.2 (U) (±0.2)	NA

[a] Not sampled during 2002.
[b] Averaged result.
[c] Results rounded to one decimal place.
[d] (2003 - 2002)/2002 x 100%.
NA = Percent change not applicable because of nondetect or not sampled previous year.
U = Nondetected in sample above contracted detection limit.

Five other monitoring wells in the K Reactor area were monitored for strontium-90. Three of the five wells had strontium-90 concentrations above 8 pCi/L, with the maximum concentration of 2,270 pCi/L in well 199-K-109A (which is downgradient of the KE fuel storage basin drain field). The fall 2002 verses fall 2003 results for these three wells are summarized in the table below. The overall trend appears to be downward.

Well	Type	Fall 2002 Sr-90 (pCi/L)	Oct. 2003 Sr-90 (pCi/L)	Percent Change[a]
199-K-107A	Monitoring	35.6 (±7.6)	35.3 (±5.3)	-1
199-K-109A	Monitoring	2,440 (±510)	2,270 (±330)	-7
199-K-34	Monitoring	31.7 (±6.8)	29.8 (±4.9)	-6

[a] (2002 - 2003)/2002 x 100%.

- Tritium: Sixteen wells are monitored for tritium in the 100-K pump-and-treat area, and four of these wells had tritium concentrations above the 20,000 pCi/L MCL in October 2003. The fall 2002 tritium results are compared to the fall 2003 results in the table below for the three wells above 20,000 pCi/L in 2003. The overall tritium trend also appears to be declining.

Well	Type	Fall 2002 Tritium (pCi/L)	Fall 2003 Tritium (pCi/L)	Percent Change[a]
199-K-18	Compliance	41,400 (±1,700)	45,850 (±3,300)	+11
199-K-32A	Monitoring	62,900 (±2,400)	44,200 (±1,700)	-30
199-K-111A	Monitoring	65,050[b] (±4,400)	30,900 (±1,200)	-52
199-K-120A	Extraction	85,600 (±8,600)	65,000 (±13,000)	-24

[a] (2003 - 2002)/2002 X 100%.
[b] Averaged result.

It is important to note that all of the wells listed above are located at the western end of the 116-K-2 Trench. The source of this tritium may be from the 116-K-2 Trench and/or from a previously unknown plume beneath the 100-K burial ground that has been displaced to the west by the mounding created by the injection network (PNNL 2002a).

Five monitoring wells in the 100-K Reactor areas are sampled for tritium. Well 199-K-106A had 367,000 ρCi/L tritium, which increased 168% from the fall 2002 value of 137,000 ρCi/L. The source of this tritium is likely the KW condensate crib (PNNL 2002b). The fall 2002 and fall 2003 results for the three wells in the 100-K Reactor areas showing tritium above the 20,000 ρCi/L MCL are summarized in the table below:

Well	Type	Fall 2002 Tritium (ρCi/L)	Fall 2003 Tritium (ρCi/L)	Percent Change[a]
199-K-106A	Monitoring	137,000 (±4,200)	367,000 (±15,000)	+168
199-K-109A	Monitoring	22,000 (±870)	53,100 (±2,400)	+141

[a] (2003 - 2002)/2002.
[b] Averaged result.

- Carbon-14: Ten wells in the 100-KR-4 OU were monitored for carbon-14 during 2003. All of these wells are located outside the pump-and-treat area. The maximum concentration in 2003 was detected in well 199-K-106A, located downgradient of the KW condensate crib, which is the probable source of the contamination. The carbon-14 concentration trend was downward in those well, with changes from 2002 to 2003 greater than 20%. The maximum carbon-14 concentrations in 2002 and 2003 and the annual changes are summarized in the table below for the five wells above the 2,000 ρCi/L carbon-14 MCL:

Well	Type	Fall 2002 C-14 (ρCi/L)	Fall 2003 C-14 (ρCi/L)	Percent Change[a]
199-K-29	Monitoring	2,900 (±92)	2,620 (±98)	-10
199-K-30	Monitoring	6,430 (±230)	6,930 (±250)	+8
199-K-33	Monitoring	8,230 (±290)	8,950 (±320)	+9
199-K-34	Monitoring	4,350 (±160)	3,050 (±110)	-30
199-K-106A	Monitoring	20,900 (±740)	15,300 (±550)	-27

[a] (2003 - 2002)/2002 x 100%.

- Nitrate: Ten wells within the pump-and-treat area were monitored for nitrate during 2003. The maximum nitrate concentration was 98.1 mg/L in compliance well 199-K-18. Nearby well 199-K-111A was characterized by 50.9 mg/L nitrate; however, the other wells in the pump-and-treat area all had nitrate concentrations below the 45 mg/L MCL. The fall 2002 and fall 2003 concentrations in the 10 wells in the pump-and-treat area and the percent change are summarized in the table below:

Well	Type	Fall 2002 NO_3 (mg/L)	Fall 2003 NO_3 (mg/L)	Percent Change[c]
199-K-111A	Monitoring	57.75	50.9	-12
199-K-18	Compliance	94.3	98.1	+4
199-K-19	Monitoring	23.5	23	-2
199-K-20	Compliance	9.74	11.1	+14
199-K-32A	Monitoring	24.3	23.9	-2
199-K-32B	Monitoring	10.2	9.49	-7
199-K-21	Monitoring	23.5	[a]	NA
199-K-22	Monitoring	14.6	15.9	+9
199-K-37	Monitoring	11.5	11.1	-4
199-K-117A	Compliance	1.73	8.41	+386

[a] Not sampled in 2003.
[b] Averaged value.
[c] (2003 - 2002)/2002 x 100%.
NA = Data not available for year to year comparison.

Samples from 12 monitoring wells in the reactor areas also were analyzed for nitrate in 2003. The range in concentrations was from 0.181 mg/L in well 199-K-108A to 99.2 mg/L in well 199-K-106A. Four of the wells were characterized by nitrate concentrations above the 45 mg/L MCL. Septic system drain fields and decontamination solutions containing nitric acid are the likely sources of this contaminant.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results, including the nitrate results for wells in the reactor areas.

3.4 100-KR-4 CONCEPTUAL MODEL UPDATE

This section describes the sources of the chromium contamination in the 100-K Area, the site hydrogeology, man-made influences on flow, and the changes to the plume caused by the treatment systems.

Sodium dichromate, $Na_2Cr_2O_7$, is a corrosion inhibitor that was added to reactor coolant water during normal operations. The hexavalent form of chromium found in sodium dichromate is highly mobile and is toxic to aquatic organisms, particularly salmon fry. The trivalent form of chromium is readily adsorbed by soil particles and is relatively insoluble in groundwater with a pH of greater than 6.0.

The primary source of chromium contamination in the 100-K Area is the 116-K-2 Trench. Large volumes of chromium-contaminated reactor coolant water and other reactor effluents were discharged into the trench between 1955 and 1971. The 116-K-2 Trench is approximately 1,250 m (4,101 ft) long, 14 m (46 ft) wide, and 5 m (16 ft) deep, in its original configuration. The trench was excavated parallel to and about 250 m (820 ft) from the Columbia River (DOE 1996b). Lists of other potentially significant sources that may have contributed to chromium contamination in the 100-K Area are presented in *Conceptual Site Models for Groundwater Contamination at 100-BC-5, 100-KR-4, 100-HR-3, and 100-FR-3 Operable Units* (BHI 1996) and *Summary of Hanford Site Groundwater Monitoring for Fiscal Year 2002* (PNNL 2003b).

The reactor coolant water and other liquids discharged to the trench contained an estimated 300,000 kg of sodium dichromate plus other chemical wastes and a significant radiological inventory. An estimated 2,100 Ci of radionuclides were disposed to the trench (Dorian and Richards 1978, WHC 1994).

The unconfined aquifer in the 100-K Area is situated in the Ringold Unit E facies of the Ringold Formation. The base of the unconfined aquifer is formed by Ringold Formation paleosols and overbank deposits. The Ringold Unit E facies in the 100-K Area may be more cemented and less eroded than in the surrounding 100 Areas. This is evidenced by Coyote Rapids, located upstream of the 100-K Area, which is made up of very resistant, well-cemented Ringold Unit E sediments. Additional hydrostratigraphic description is presented in the *Remedial Design Report and Remedial Action Work Plan for the 100-HR-3 and 100-KR-4 Groundwater Operable Units Interim Action* (DOE-RL 1996b) and *Geology of the 100-K Area, Hanford Site, South-Central Washington* (WHC 1993).

Groundwater flow in the 100-K Area is predominantly to the northwest. Flow direction is affected by the elevation (stage) of the Columbia River, artificial mounding caused by operational practices, and hydrogeology.

Groundwater flow is generally toward the Columbia River, except from May through August when the elevation (stage) is higher because of increased upriver dam releases. These releases raise the river level and may reverse the groundwater flow direction (inland flow). The releases are managed to balance summer irrigation demand and power (electricity) production and to maintain safe river elevations for fisheries management.

When the K Reactors were in operation, the full length of the 116-K-2 Trench was filled to capacity with reactor coolant water. A groundwater mound about 6 m (19.7 ft) higher than the natural water table caused flow inland (southeast) and toward the river (northwest). Any mounding should have long since dissipated; however, some contaminants may have been retained in the vadose zone.

Hydrogeology has a strong influence on flow rate in the 100-K Area. The hydraulic conductivities vary greatly from 200 m/day (656 ft/day) in local areas downgradient of the 116-K-2 Trench to 2 m/day (6.6 ft/day) in the injection well area. The range of hydraulic conductivities is likely a function of the degree of cementation of the Ringold Unit E sediments. Slug test results are reported in BHI (1996).

The original 100-K pump-and-treat target area was oblong in shape, on the downstream side of the 116-K-2 Trench, extending the full length of the trench (Figure 3-10). The 100 µg/L chromium isopleth extended the full length of the trench. Six extraction wells were constructed to capture the entire plume known at the time.

The November 2003 100-K chromium plume map is shown in Figure 3-10. Two remaining areas are surrounded by 100 µg/L isopleths; however, hexavalent chromium was measured at 98 µg/L in well 199-K-126. The extraction well network now includes eight wells, including well 199-K-126. Monitoring well 199-K-130 was added to the network during 2003 to monitor downstream concentrations of chromium. This well contained 81.4 µg/L of hexavalent chromium in November 2003.

The pump-and-treat system has removed approximately 220 kg of chromium from the aquifer since startup in 1997. The mass of chromium remaining in the aquifer is unknown. However, it also is significant that the size of the high-concentration portion of the plume (>100 μg/L) is shrinking. This is evidence that the pump-and-treat system is effective in reducing contaminant mass.

Chromium concentrations in inland monitoring well 699-78-62 have remained about 35 to 40 μg/L. This plume may have been pushed inland by mounding during operations.

3.5 QUALITY CONTROL RESULTS FOR 100-K MONITORING DATA

The QC results for the 100-K sampling included field testing or offsite laboratory testing for hexavalent chromium and total chromium. Additionally, offsite laboratory tests were run for strontium-90 and tritium.

The highlights of QC data for 100-KR-4 Area CY03 sampling are summarized in the table below. Tables listing complete QC results are found in Appendix F.

Type Quality Control Sample	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Replicate	10	10	100%
Field/offsite laboratory split (hexavalent chromium)	13	10	77%
Field/offsite laboratory splits (hexavalent chromium/total chromium)	7	6	86%
Offsite laboratory replicates (total chromium)	6	5	83%
Offsite laboratory replicates (strontium-90)	7	6	86%
Offsite laboratory replicates	5	5	100%

The EPA's functional guideline for field-tested replicates is ±20% (EPA 1988), and all field replicates satisfied this requirement. There are no functional guidelines for split results or offsite laboratory replicates, but sample pair results correlated well because no more than one sample pair in any QC category had an RPD of >20%.

3.6 CONCLUSIONS

- ***RAO #1: Protect aquatic receptors in the river bottom substrate from contaminants in groundwater entering the Columbia River.*** The RAO cleanup goal for compliance wells is 22 μg/L based on the 11 μg/L ambient water quality criterion in place at the time of the signing of the ROD.

  Results:

  - Approximately 517.6 million L of groundwater were treated during 2003, and 36.7 kg of hexavalent chromium were removed.

- Chromium concentrations decreased in all extraction wells but remained above the RAO of 22 μg/L in all extraction wells. The maximum chromium concentration in an extraction well was 119 μg/L in well 119-K-116A. This well also had the highest chromium concentration in 2002 (133 μg/L).
- The furthest downstream monitoring well, 199-K-130, had an average chromium concentration of 81.4 μg/L in October 2003. This well was first sampled in March 2003.
- The maximum strontium-90 concentration in the pump-and-treat area of influence was at compliance well 199-K-114A. The concentration was 20.2 ρCi/L of strontium-90 in October 2003.
- Four pump-and-treat area wells had tritium concentrations above the 20,000 ρCi/L MCL. The maximum concentration was 45,850 ρCi/L in compliance well 199-K-18, which is an increase of 11% over 2002.
- The area enclosed by the 100 μg/L isopleth has decreased since November 2002 when compared to the 1995 baseline 100-K Area chromium plume.
- Compliance well 199-K-126 was converted to an extraction well in January 2003 to supplement capture of the downstream portion of the chromium plume.

• ***RAO #2: Protect human health by preventing exposure to contaminants in groundwater.***

  Result: The interim remedial action ROD establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)
  - Regulatory agency notification of any trespassing incidents.

  The effectiveness of institutional controls was presented in the *2003 Sitewide Institutional Control Annual Assessment Report for the Hanford CERCLA Response Actions* (DOE-RL 2003). The findings of the report indicate that institutional controls were maintained to prevent public access as required.

• ***RAO #3: Provide information that will lead to a final remedy.***

  Results: The following information will be used in determining the effectiveness of ongoing operations in reaching a final remedy:

  - <u>Treatment cost</u>: Treatment cost for the period was $2,215,800. At a yearly production rate of 517.6 million L and 36.7 kg of chromium removed, the treatment cost equates to about $0.004/L, or $60/g of chromium removed. The treatment costs for fiscal year 2003 (FY03) were lower than the $69/g of chromium removed in FY02.

- System efficiency: The CY03 95.2% removal efficiency for the treatment system was similar to the 95% reported in CY02.
- Hydraulic impact: A numerical model was used to estimate the effectiveness of capture and containment of the pump-and-treat system. Based on numerical modeling, the 100-KR-4 system, with nine extraction wells operating at or near their designed flow rates, captures groundwater from the targeted area all along the length of the trench. This groundwater would otherwise discharge into the Columbia River. Because the extraction wells penetrate the aquifer, it is assumed that contamination throughout the full thickness of the unconfined aquifer is captured.
- Effectiveness of contaminant removal in aquifer: For CY03, approximately 517.6 million L of water were treated from the 100-KR-4 OU, which resulted in the removal of 36.7 kg of chromium. These values are slightly higher than 445.7 million L of water removed and 35.5 kg of chromium removed in CY02. Since initiation of the system in October 1997, more than 2.21 billion L of water have been treated, resulting in the removal of approximately 220.7 kg of chromium from the 100-KR-4 aquifer.
- Maintain data: Pertinent data have been maintained in the HEIS database and the project-specific database.
- System availability: Overall system availability for the reporting period was approximately 99.3%, which is the slightly higher than the 98.3% reported in CY02. System availability is a ratio of the actual time that the system is on-line to the total time available for operation. Downtime includes scheduled and unscheduled maintenance; system modifications; and outages associated with weather, power loss, and other acts of nature.

3.7 RECOMMENDATIONS

- Determine the best location of a new downgradient monitoring well to establish the terminal (northeast) extent of the chromium plume using monitoring well, aquifer tube, and seep data.
- Determine the feasibility of converting new monitoring well 199-K-130 to an extraction well to optimize capture in the northeast portion of the plume.
- Establish a long-term strategy to address the widely distributed but relatively low hexavalent chromium concentrations in the 100-KR-4 OU.

Figure 3-1. Location of the 100-KR-4 Operable Unit.

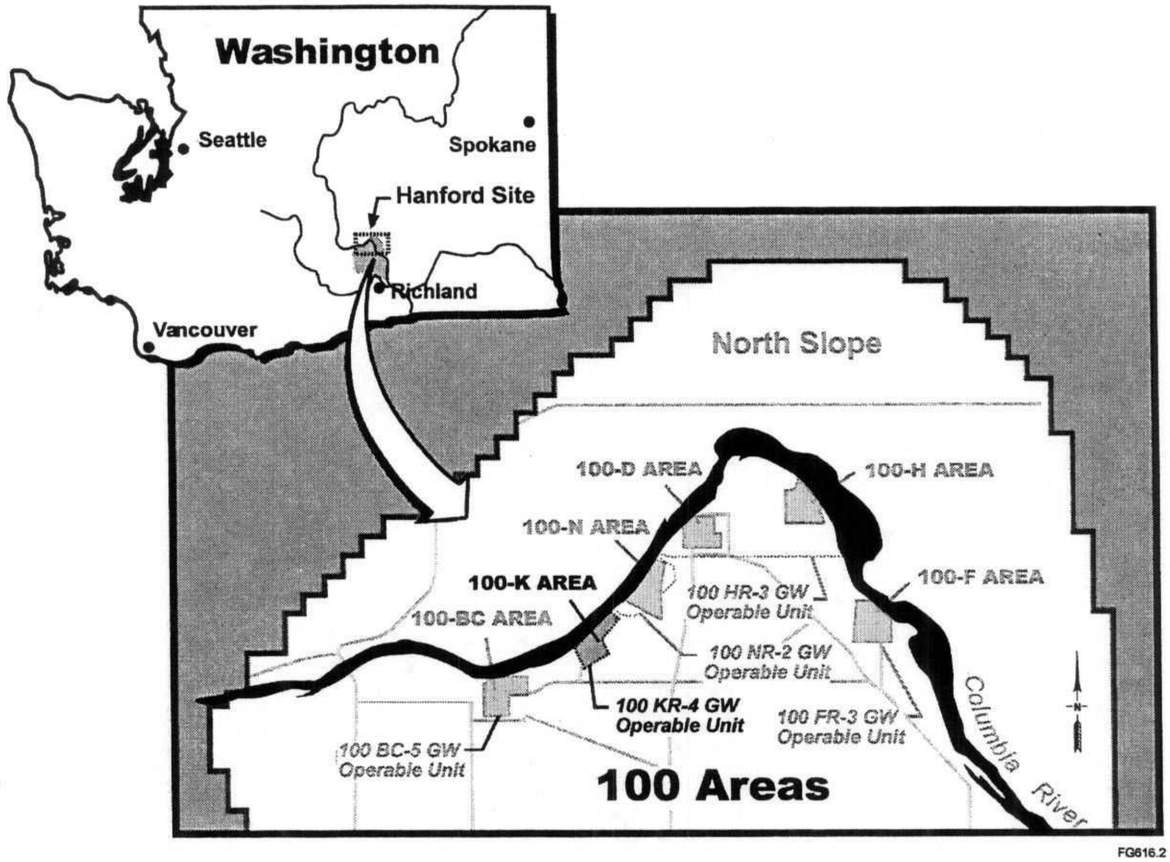


Figure 3-2. 100-KR-4 Operable Unit Wells and Aquifer Sampling Tubes.

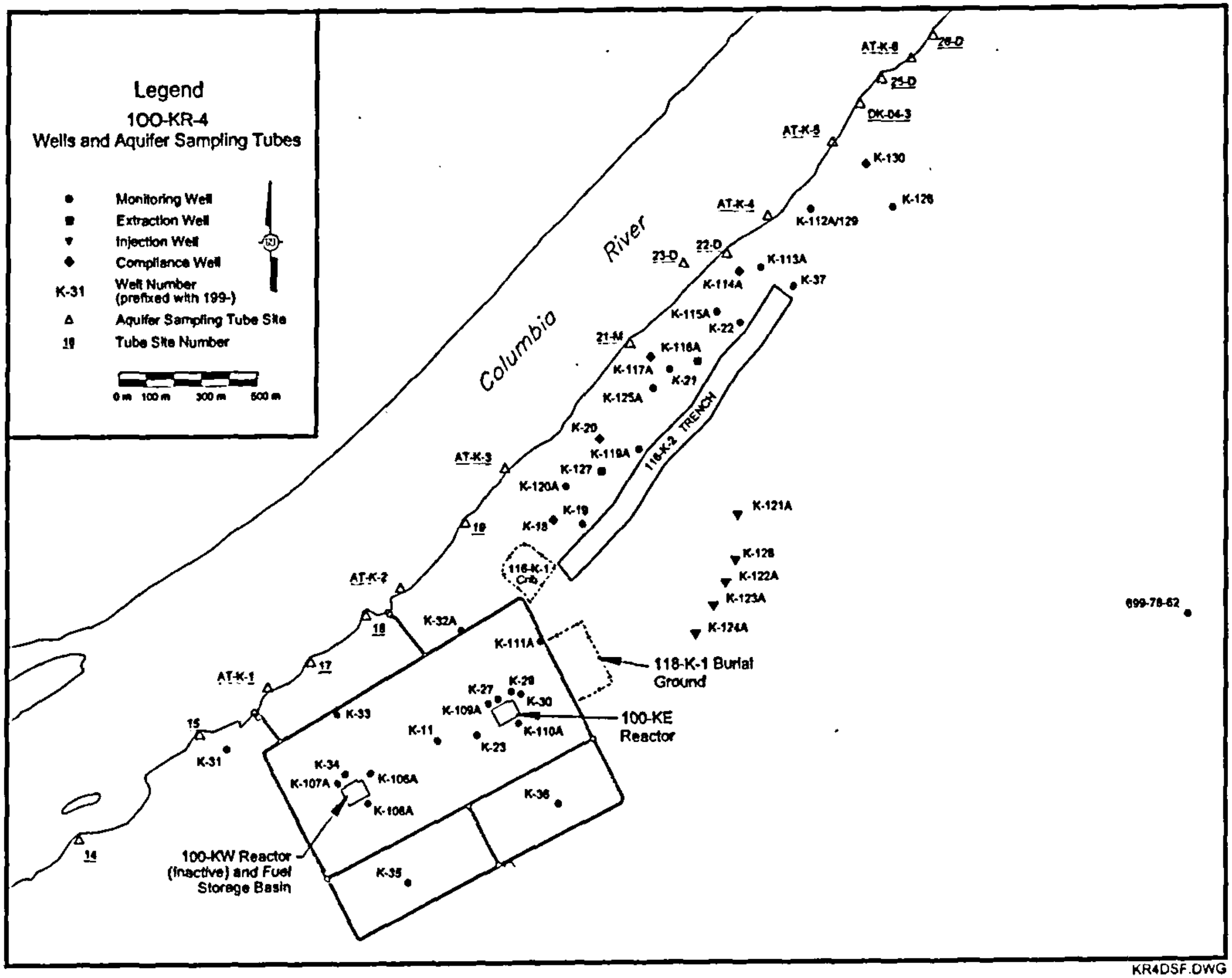


Figure 3-3. 100-KR-4 Operable Unit Pump-and-Treat System Schematic.

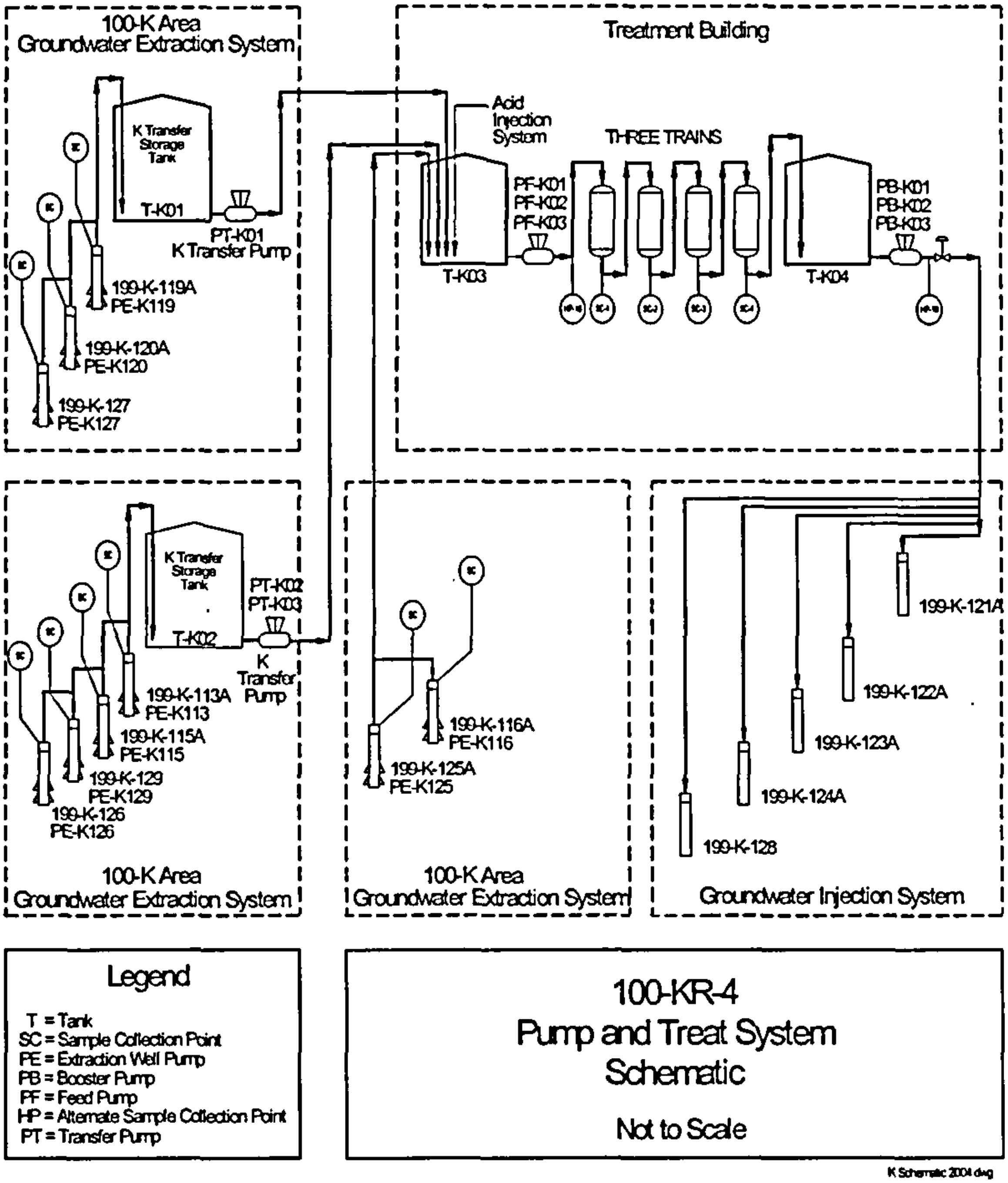


Figure 3-4. 100-KR-4 Pump-and-Treat Trends of Average Removal Efficiencies.

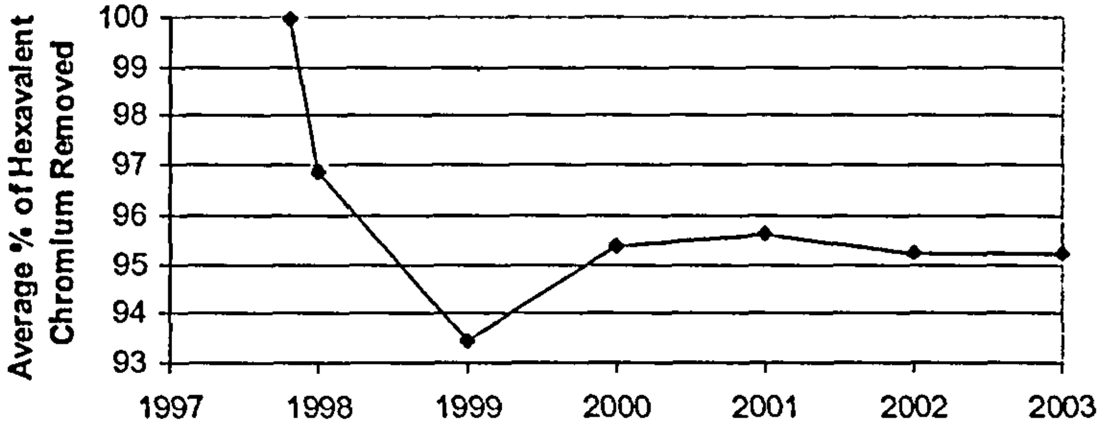
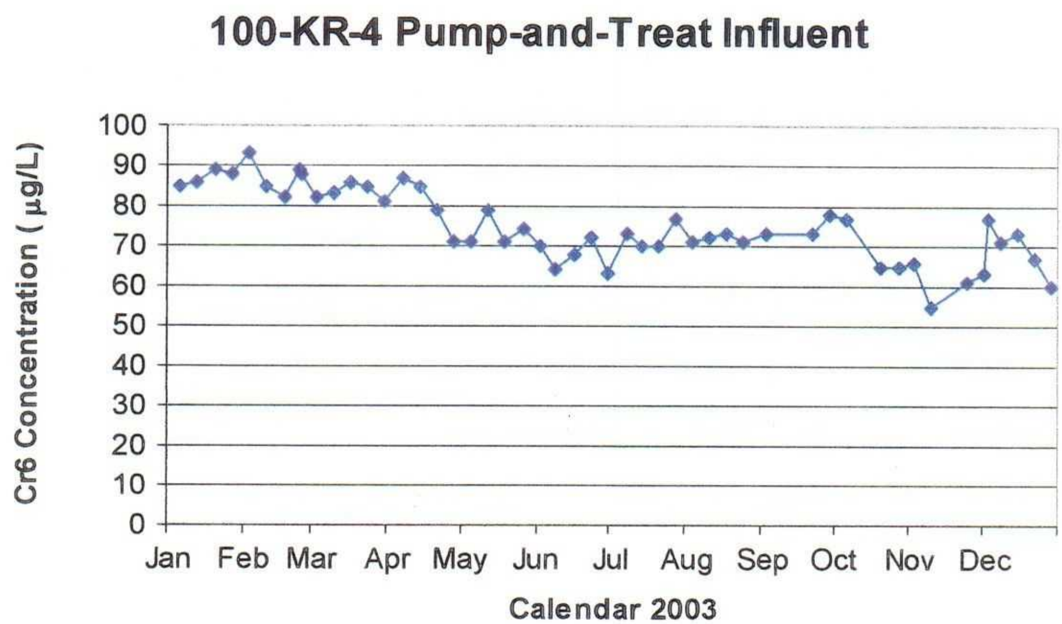


Figure 3-5. 100-KR-4 Pump-and-Treat Trends of Influent and Effluent Hexavalent Chromium Concentrations, Calendar Year 2003.



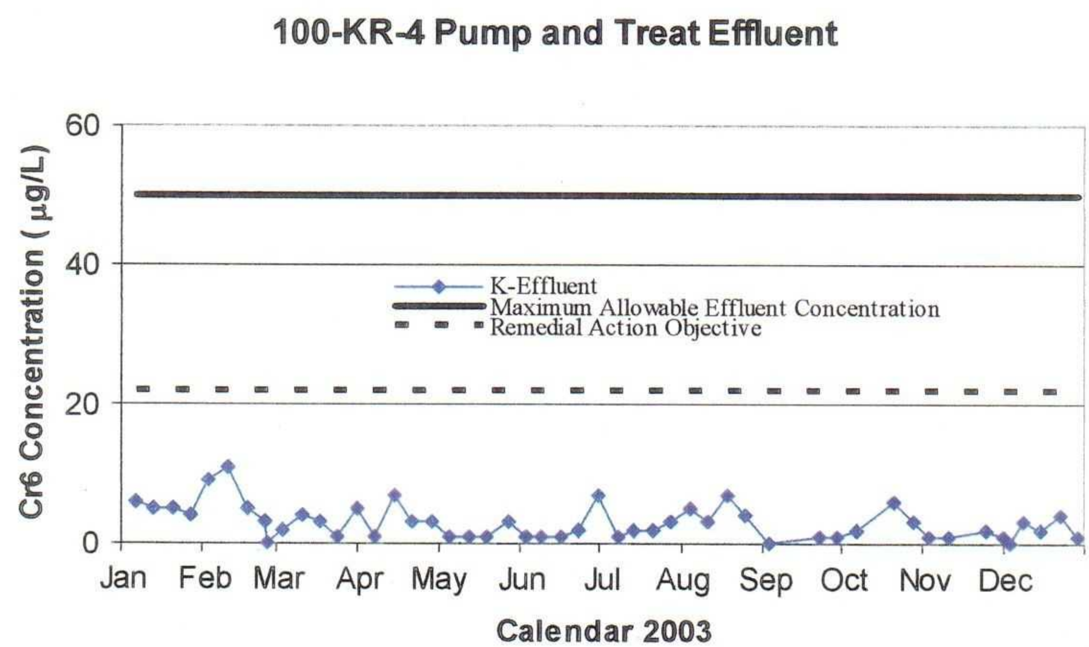
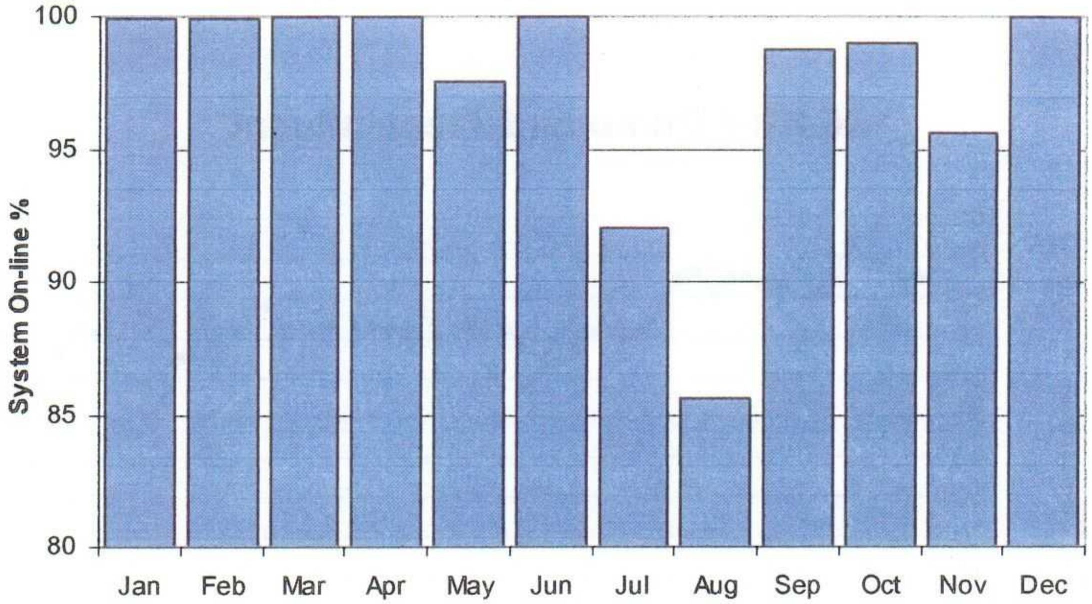


Figure 3-6. 100-KR-4 System Availability and On-Line Percentages, Calendar Year 2003.



February 27: System shut down for 0.5 hours due to leak trip due to overflow into sump.

May 19: System shut down for 0.5 hours for unknown reason.

April 24: System shut down for 15.5 due to weather-caused power outage.

July 1: System shut down for 1 hour due to fuse inspection.

July 6: System shut down for 14 hours due to scheduled power outage.

August 14: System shut down for 91 hours due to scheduled power outage.

September 2 and 4: System shut down for a total of 9 hours to perform recirculating acid for scale removal.

October 13: System shut down for 2 hours for acid bath of A1 vessel.

October 22: System shut down for 1.5 hours due to faulty sump float that indicated a leak.

December 9: System shut down for 1.5 hours to install new callout system.

Figure 3-7. 100-KR-4 Chromium Plume, Fall 2003.

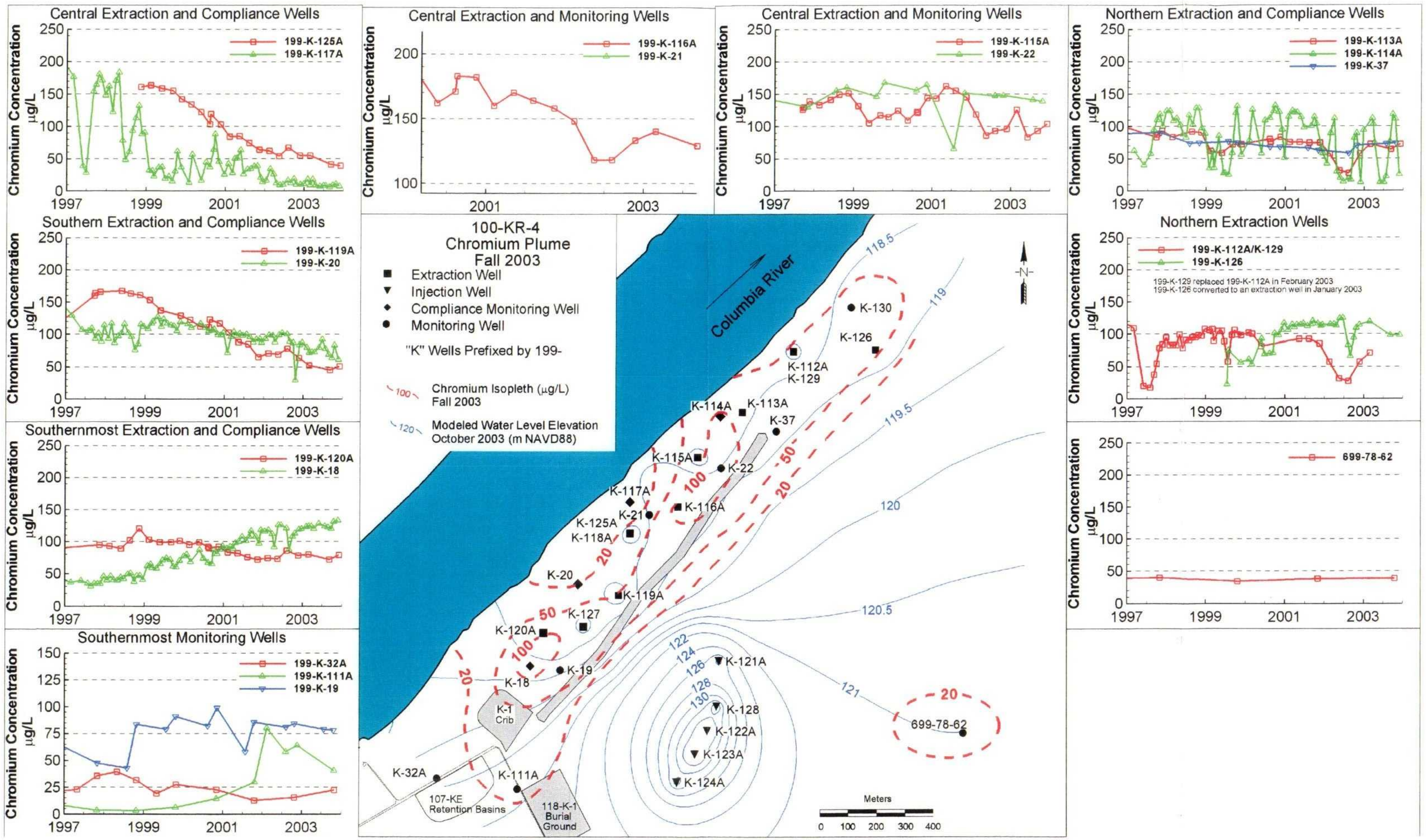


Figure 3-8. Estimated Steady-State Hydraulic Capture Zone Developed by 100-KR-4 Operable Unit Extraction Wells.

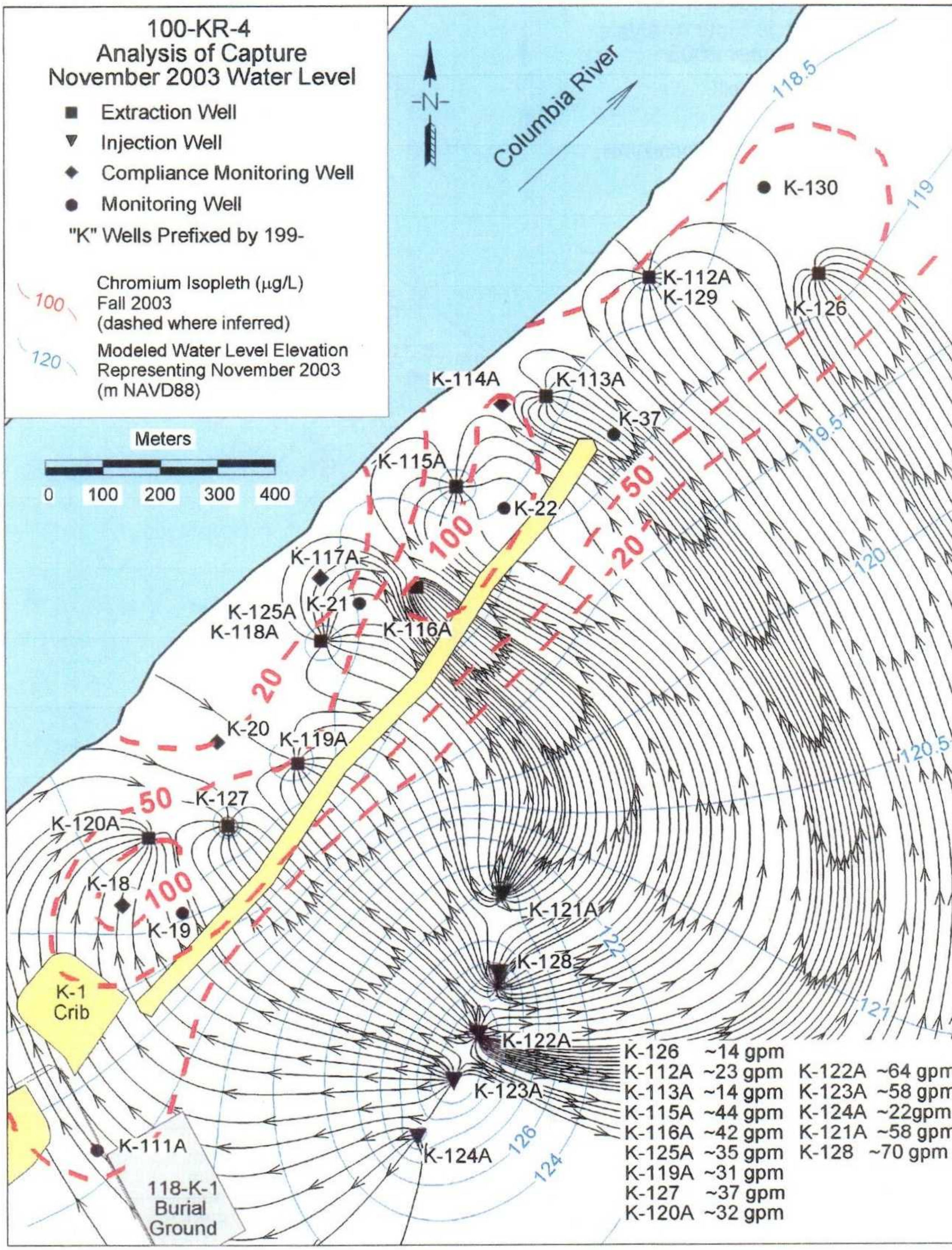


Figure 3-9. Evaluation of 10 0-KR-4 Hydraulic Capture Using Water Particle Flow Analysis.

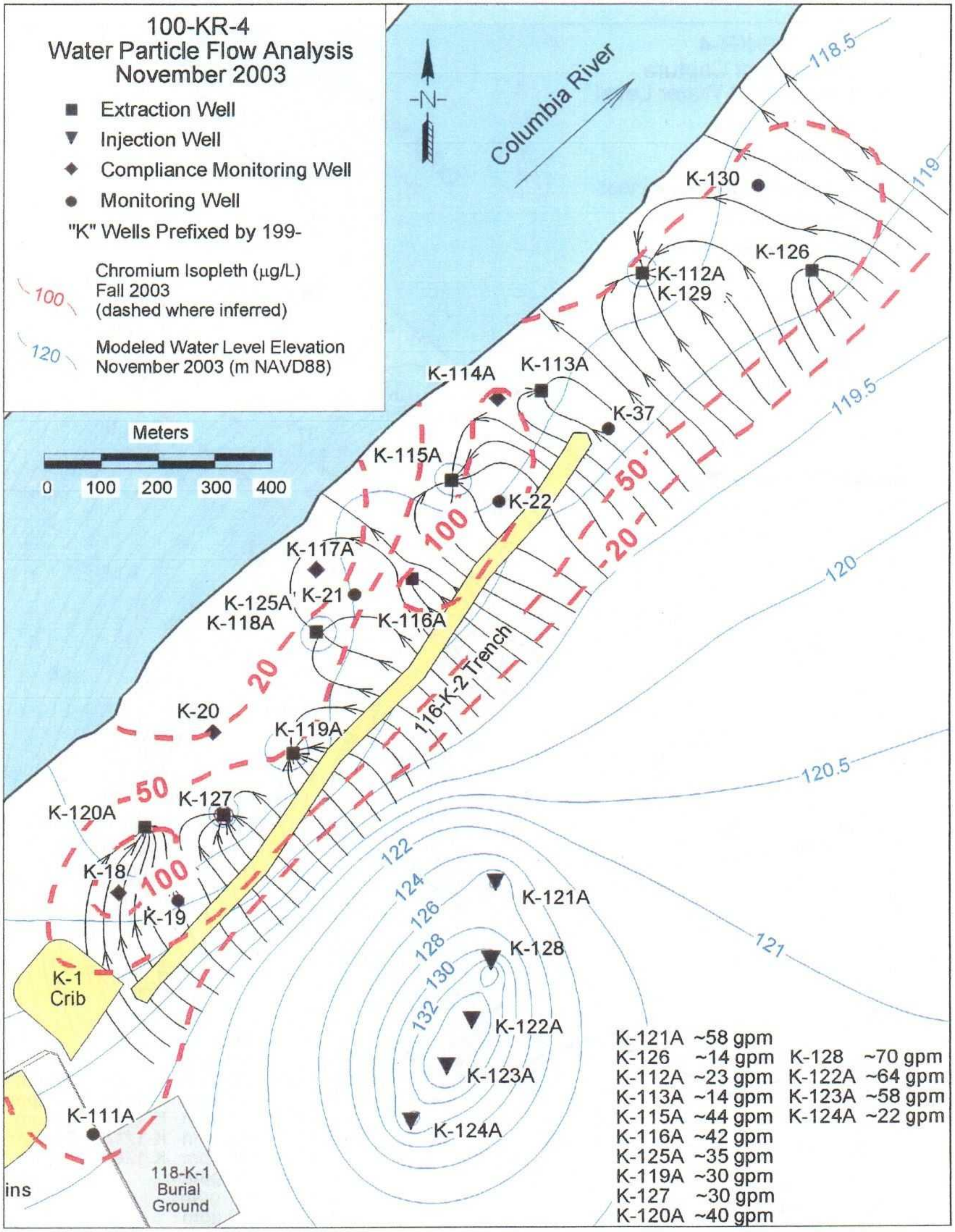


Figure 3-10. 100-K Chromium Plume Map and Baseline, November 2003.

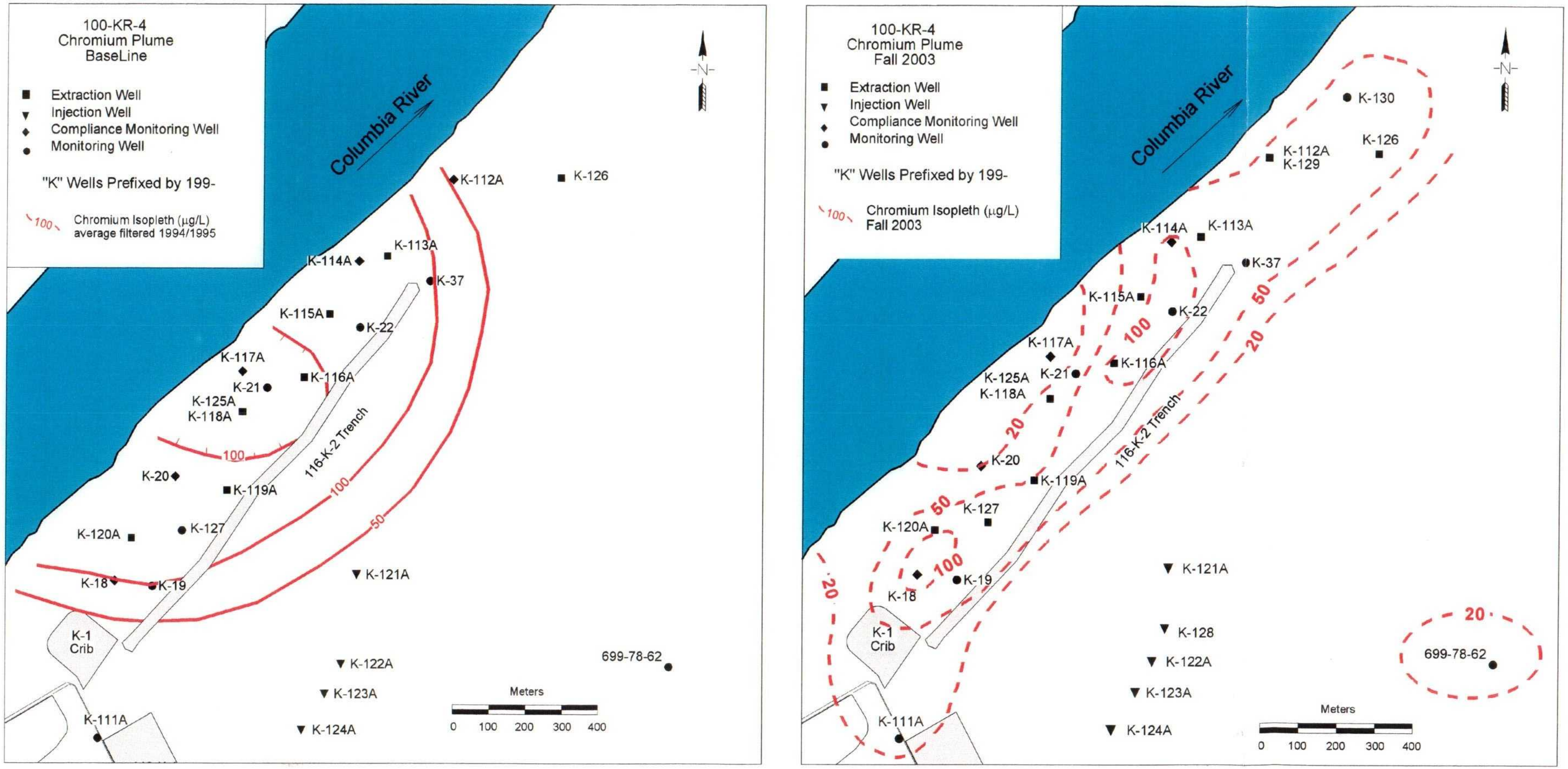


Table 3-1. 100-KR-4 Water-Level Data Used to Develop and Calibrate Numerical Groundwater Flow Models.

Well	Model Analysis, Nov. 2003		Measured Water-Level Elevation, Nov. 2003 (m)	Modeled Water-Level Elevation, Nov. 2003 (m)
	Extraction Rate (L/min)	Injection Rate (L/min)		
199-K-122A	87	—	116.117	116.638
199-K-113A	53	—	116.516	116.423
199-K-115A	167	—	115.693	115.358
199-K-116A	159	—	118.294	118.616
199-K-125A	133	—	116.134	115.297
199-K-119A	117	—	116.613	116.059
199-K-126	53	—	117.089	118.289
199-K-127	140	—	116.958	116.478
199-K-120A	121	—	118.074	118.113
199-K-121A	—	220	128.408	132.920
199-K-122A	—	242	126.226	147.207
199-K-123A	—	220	130.053	147.554
199-K-124A	—	83	128.903	137.574
199-K-128	—	245	127.844	143.759
199-K-114A	—	—	118.468	118.354
199-K-37	—	—	118.736	118.848

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4.0 100-NR-2 PUMP-AND-TREAT SYSTEM

The 100-NR-2 groundwater OU is located along the Columbia River between the 100-KR-4 OU and the 100-HR-3 OU (Figure 4-1). The 100-NR-2 OU represents the groundwater underlying the source OUs that are associated with the 100-N Area. The 100-NR-2 pump-and-treat system is currently operating to retard movement of contaminated groundwater toward the Columbia River and, in the process, is removing small amounts of strontium-90. Figure 4-2 presents the general layout of the 100-NR-2 pump-and-treat system, wells, and facilities.

This section provides the annual performance report for the 100-NR-2 pump-and-treat system required by the *Interim Remedial Action Record of Decision (ROD) Declaration, USDOE Hanford 100 Area, 100-NR-1 and 100-NR-2 Operable Units, Hanford Site* (EPA et al. 1999). The purpose of this section is to evaluate treatment system and aquifer performance data collected during implementation of the expedited response action to assess compliance with the goals described in the ROD. Contaminant distributions and trends in the OU also are evaluated.

The following subsections summarize and evaluate the performance of the pump-and-treat system, the response of the aquifer in relation to these goals, and the OU contaminants. Section 4.1 provides a brief overview summary of activities pertaining to the 100-NR-2 pump-and-treat system and source area remedial actions that have occurred within the OU for CY03. Section 4.2 focuses on the treatment system performance. Section 4.3 considers the aquifer response, including the baseline conditions, hydraulic effects, numerical modeling, contaminant changes during the pump-and-treat operations, and contamination distributions and trends throughout the OU. Section 4.4 presents the conceptual model. Section 4.5 discusses the QC of the analytical samples. Conclusions and recommendations are presented in Section 4.6. Cost information is presented separately in Section 5.0.

4.1 SUMMARY OF SOURCE AREA OPERABLE UNIT ACTIVITIES

A summary of activities pertaining to the 100-NR-2 pump-and-treat system and source area within the 100-NR-2 OU in CY03 is as follows:

- A literature search and evaluation of existing aquatic and riparian receptor data for the 100-N Area was completed (*Evaluation of Aquatic and Riparian Receptor Impacts at the 100-N Area: Literature and Data Review* [PNNL 2003a]).
- Initial laboratory and greenhouse scoping studies of in situ apatite sequestration and phytoremediation were initiated to further evaluate alternative remediation technologies for controlling strontium-90 flux to the river.
- Field testing was initiated for a passive remediation method for removal of diesel fuel at monitoring well 199-N-18A.
- Surface and near-surface remediation continued at the 1301-N Liquid Waste Disposal Facility (LWDF).
- The 1324-N surface impoundment (120-N-2) and the 1324-NA percolation pond (120-N-1) were revegetated.

4.2 100-NR-2 TREATMENT SYSTEM PERFORMANCE

This section summarizes the treatment system operations and sampling activities that occurred during CY03. This information includes system availability, mass of contaminants removed during operations, contaminant removal efficiencies, and quantity and quality of extracted and disposed groundwater. Additional operational details are found in the associated appendices as called out in the text.

4.2.1 System Operation

The treatment facility includes an ion-adsorption system that uses a natural zeolite (clinoptilolite) to remove strontium-90 from the groundwater. In 2003, no major operational modifications were made that changed the performance of the pump-and-treat system. Figure 4-3 presents the current system process flow. A summary of operational parameters for CY03 and for total performance is as follows:

Total processed groundwater:	
Total since September 1995 startup (million L)	902.3
Total for CY03 (million L)	114.1
Mass of strontium-90 removed:	
Total since September 1995 startup (Ci)	1.48
Total for CY03 (Ci)	0.18
Average total flow rate of extraction wells for CY03 (L/min)	244.1
Average extraction well production range (L/min)	40.1 to 143.8
Average percent removal	88.8
Summary of 2003 operational parameters:	
Total possible run-time (hours)	8,760
Scheduled downtime (hours)	789.5
Planned operation (hours)	7,970.5
Unscheduled downtime (hours)	194
Total time on-line	7,776.5
Scheduled system availability (%)	97.6
Total system availability (%)	88.8

Key operational and system highlights for CY03 are as follows:

- The system availability of 97.6% for CY03 was slightly lower than the CY02 value of 98.8%. The system was on-line 88.8% of the total hours during the year, which was lower than the 95% reported for CY02. The lower performance percentages were a result of additional hours needed for scheduled maintenance and a higher rate of unscheduled down time because of lock-and-tag issues in September 2003.
- The average percentage removal for CY03 was 88.8% compared to 90% reported for CY02. The interim ROD specifies a minimum removal efficiency of 90%. Because of cold temperatures, the system was not shut down in December 2003 to prevent freezing. This resulted in lower removal efficiency for the period because clino could not be changed. Figure 4-4 presents the monthly on-line percentages and events impacting system availability for the reporting period.

- As shown in Figure 4-5, the CY03 average influent activity for strontium-90 was 1,878 ρCi/L. The average effluent activity for strontium-90 was 270 ρCi/L. These averages were slightly lower than the CY02 influent value of 1,914 ρCi/L and effluent value of 327 ρCi/L.

Historical presentation of operational parameters, total system performance, and activities for influent and effluent are presented in Appendix B.

4.3 AQUIFER RESPONSE IN 100-NR-2

This section describes the general hydrogeologic conditions in the 100-N Area, numerical modeling conducted to evaluate the extraction well network, and changes in contaminant concentrations in monitoring wells.

4.3.1 Hydraulic Conditions at 100-NR-2

- The most prevalent groundwater flow direction is northwest, as shown in Figure 4-6. During spring months, the river elevation is generally higher because of increased run-off and to provide more irrigation water and aid fish migration. This flow reversal from northwest to southeast is clearly shown in Figure C-8 of Appendix C, where the May and June 2003 river elevations are higher than near-river wells.
- The average November 2003 river-stage elevation was 115.38 m (378.5 ft) compared to the average 1991-2003 November river-stage elevation of 115.19 m (377.9 ft).
- The November 2003 hydraulic gradient was 0.002 to 0.004 toward the northwest based on the groundwater surface elevation contours shown in Figure 4-6.
- The estimated groundwater flow velocity at 100-NR-2 ranged from 0.07 to 1.3 m/day (0.23 to 4.27 ft/day) based on a hydraulic conductivity of 6.1 to 37 m/day (20.01 to 121.39 ft/day), porosity of 0.1 to 0.2, and gradient of 0.002 to 0.004 (PNNL 2002b).
- The average 2003 extraction well pumping rates ranged from 40.1 L/min (10.6 gpm) in well 199-N-75 to 143.8 L/min (38 gpm) in well 199-N-106A. This compares to a range of 39 L/min (10.3 gpm) to 138 L/min (36.5 gpm) in 2002.

4.3.2 Numerical Modeling

A summary of the numerical modeling results supporting the 100-NR-2 pump-and-treat operations is as follows:

- The original baseline 1997 strontium-90 pump-and-treat plume is within the 2003 modeled capture zone of the 100-NR-2 extraction well network, as shown in Figure 4-7.
- The modeled November 2003 flow lines in Figure 4-7 compare very closely with the predicted capture flow lines in *N-Springs Expedited Response Action Performance Evaluation Report* (DOE-RL 1996a). This comparison suggests that the pump-and-treat system performance is consistent with the results of the predicted model.
- A list of the modeled water table elevations and average modeled flow rates is presented in Table 4-1.

- A measured drawdown/buildup analysis was not necessary to support the 2003 modeled results because of the strong similarity between 2002 and 2003 extraction well pumping rates, river stage, and hydraulic gradient. This analysis may be conducted in future years if conditions vary significantly.

A more detailed discussion of model development is presented in Appendix D.

4.3.3 Contaminant Monitoring

This section summarizes the 100-N Area groundwater monitoring results collected to support the interim remedial action and OU monitoring program during CY03.

The principal groundwater COCs in the 100-N Area are strontium-90, tritium, chromium, manganese, sulfate, and petroleum hydrocarbons. The CERCLA sampling is conducted in March and September.

4.3.3.1 Strontium-90 Monitoring Results

Strontium-90 was monitored in 4 extraction wells and 16 monitoring wells during CY03. Figure 4-6 displays the CY03 strontium-90 plume and associated historical trends. The configuration of the strontium-90 plume has remained relatively unchanged since the startup of pump-and-treat operations.

The maximum strontium-90 concentration was found in well 199-N-67, where it was measured at 8,000 pCi/L (±1,200 pCi/L). This well is located downgradient of the 1301-N LWDF and has declined from 26,000 pCi/L in March 1998. The greatest increase in strontium-90 concentration from 2002 to 2003 was detected in extraction well 199-N-75, which increased from 394 pCi/L (±41 pCi/L) to 541 pCi/L (±79 pCi/L). Strontium-90 data for wells in which strontium-90 changed greater than 20% from 2002 to 2003 are summarized below:

Well	Type	Fall 2002 Sr-90 (pCi/L)	Fall 2003 Sr-90 (pCi/L)	Percent Change[b]
199-N-105A	Extraction	1,040 (±220)	664 (±99)	-36
199-N-75	Extraction	394[a] (±41)	541 (±79)	+37
199-N-2	Monitoring	662[a] (±107)	118 (±18)	-82
199-N-67	Monitoring	11,400 (±1,200)	8,000 (±1,200)	-30
199-N-76	Monitoring	296 (±30)	202 (±30)	-32
199-N-81	Monitoring	889[a] (±146)	638[a] (±80)	-28

[a] Averaged result.
[b] (2003 - 2002)/2002 x 100%.
\+ = increase
\- = decrease

4.3.3.2 Seeps

Seeps are surface discharge areas at the Columbia River shoreline and are sampled annually by the Sitewide Environmental Surveillance Project. The number of seeps has decreased in recent years because effluent has not been disposed to the LWDF since 1991 and the lowered river stage in drought years has resulted in a lowered water table reducing the number of discharge areas. However, seeps sampled in October 1991 along a section of shoreline approximately parallel to the 1301-N LWDF contained up to 1,800 pCi/L of strontium-90 (PNNL 2002b). The offshore extent of the plume into the river substrate (hyporheic zone) is not known because there are no river substrate sampling sites located off the 100-N Area shoreline.

4.3.3.3 Contaminants of Concern Monitoring Results

Other COCs in the 100-N Area include tritium, chromium, manganese, nitrate, sulfate, and petroleum hydrocarbons (EPA et al. 1999). The results of the COC monitoring for CY03 are summarized as follows. Additional COC details are available in Appendix E.

- Tritium: Tritium was monitored in 19 wells during CY03. The highest tritium concentration of 31,400 pCi/L (±1,500) was in well 199-N-14, located northwest of the 1301-N LWDF. Tritium concentrations were above the 20,000 pCi/L MCL in five wells sampled during CY03 compared to seven wells sampled in CY02. Concentrations for tritium overall appear to be declining. Tritium data are summarized in the table below for wells in which concentrations changed more than 20% from 2002 to 2003 or concentrations were above the 20,000 pCi/L MCL. The estimated amount of tritium retained in the recirculation cell set up by the extraction and injection well network was approximately 2 Ci for 2003. The tritium retained in the recirculation cell is not available for release to the river.

Well	Type	Fall 2002 H-3 (pCi/L)	Fall 2003 H-3 (pCi/L)	Percent Change[b]
199-N-14	Monitoring	37,350[a] (±3,800)	31,400 (±1,500)	-16
199-N-27	Monitoring	20,300 (±2,100)	19,700 (±970)	-3
199-N-32	Monitoring	25,300 (±2,600)	25,100 (±1,200)	-1
199-N-51	Monitoring	8,800 (±930)	11,300 (±620)	+28
199-N-64	Monitoring	8,820 (±930)	16,200 (±830)	+84
199-N-75	Monitoring	20,100[a] (±2,050)	20,400 (±1,000)	+2
199-N-76	Monitoring	29,800 (±3,000)	22,400 (±1,100)	-25
199-N-80	Monitoring	25,600 (±2,600)	21,700 (±1,100)	-15
199-N-92A	Monitoring	21,500 (±2,200)	12,500 (±680)	-42
199-N-96A	Monitoring	1,980 (±260)	3,735[a] (±295)	+89

[a] Averaged result.
[b] (2003 - 2002)/2002 X 100%.

- Chromium: Chromium is monitored in 25 wells but was detected above 22 µg/L only in well 199-N-80, completed in the first producing horizon in the confined aquifer. The CY03 concentration was 168 µg/L, which is the same concentration measured in CY02. The source of the elevated chromium may be deterioration of the stainless-steel well casing. The highest CY03 filtered total chromium concentration in a well screened in the unconfined aquifer in the 100-N Area was 15.7 µg/L in well 199-N-64. Therefore, it appears that chromium contamination is not a widespread problem in the 100-N Area.

- Manganese: Manganese is elevated above the 50 µg/L MCL only in wells 199-N-16 and 199-N-18 where it was detected at 1,110 µg/L and 3,700 µg/L, respectively. Well 199-N-18 is located adjacent to a diesel spill site, and the source of the elevated manganese may be due to diesel additives, corrosion of steel casing and/or reducing conditions caused by degradation of the residual diesel fuel still present in the aquifer. Well 199-N-16 is located downgradient from other historic diesel spill sites; dissolved oxygen has been low in this well and the cause of the elevated manganese at this site also may be petroleum hydrocarbon related.

- Nitrate: Nitrate concentrations exceeded the 45 mg/L MCL in six monitoring wells during CY03, namely wells 199-N-18, 199-N-2, 199-N-3, 199-N-21, 199-N-32, and 199-N-67. Nitrate concentrations vary greatly in the 100-N Area. For example, concentrations in well 199-N-67 were 49.8 mg/L in fall 2002 and increased to 228 mg/L in fall 2003. The source of the nitrate is unknown at this time, although nitrate is widespread throughout groundwater at the Hanford Site.

  Nitrate data are summarized in the table below for wells in which concentration changed more than 20% from 2002 to 2003 or were above the 45 mg/L MCL:

Well	Type	Fall 2002 NO_3 (mg/L)	Fall 2003 NO_3 (mg/L)	Percent Change[b]
199-N-16	Monitoring	19.3	3.9	-80
199-N-18	Monitoring	0.195	0.487	+150
199-N-2	Monitoring	25.1[a]	59.8	+138
199-N-21	Monitoring	47.8	49.1	+3
199-N-3	Monitoring	52.1[a]	62.4	+20
199-N-32	Monitoring	46.1	62.9	+36
199-N-64	Monitoring	25.0	33.2	+32..8
199-N-67	Monitoring	49.8	228	+358
199-N-75	Monitoring	27.9[a]	36.3	+30
199-N-81	Monitoring	34.4[a]	25.4	-26
199-N-96A	Monitoring	43.4	26.4[a]	-39
199-N-99A	Monitoring	26.9[a]	15.1	-44

[a] Averaged result.
[b] (2003 - 2002)/2002 x 100%.

- Sulfate: None of the 18 well samples analyzed for sulfate in the fall 2003 were above the 250 mg/L secondary drinking water standard.

  Sulfate data are summarized in the following table for wells in which concentrations changed more than 20% from 2002 to 2003:

Well	Type	Fall 2002 SO_4 (mg/L)	Fall 2003 SO_4 (mg/L)	Percent Change[b]
199-N-16	Monitoring	101.0	141.0	+40
199-N-2	Monitoring	78.7[a]	57.1	-27
199-N-64	Monitoring	143	75.6	-47
199-N-67	Monitoring	77.1	49.4	-36
199-N-81	Monitoring	118.5[a]	80.6	-32
199-N-96A	Monitoring	96	117.5[a]	+22

[a] Averaged result.
[b] (2003 - 2002)/2002 x 100%.

- Petroleum hydrocarbons: Well 199-N-18 monitors the area of 100-N where a 300,000-L petroleum leak occurred during the 1960s. The total petroleum hydrocarbons (TPH)-diesel range fluctuated from 440 mg/L in September 2002 to 630,000 mg/L in March 2003 and 350 mg/L in September 2003. The March 2003 sampling also noted an inch of free product in this well. Similarly, the TPH-gasoline range declined from 15 mg/L in September 2002 to 6.1 mg/L in September 2003.

  A passive treatment method to remove residual amounts of diesel from well 199-N-18 was deployed in October 2003. This approach was chosen because the layer of floating petroleum is too thin for removal by active remediation methods. The passive method employs a polymer (Smart Sponge™) with a molecular structure that selectively absorbs petroleum from the surface of the water (i.e., a sponge) while the device floats at the air/hydrocarbon/water interface. A bundle of four, 0.3-m (1-ft)-long cylinders of the material was lowered into the well for a 2-week period after which it was removed, weighed, and replaced with a new pre-weighed bundle. This procedure will be repeated every 2 weeks for a year. The one-year observation period ends in October 2004 and will be used to evaluate the mass removal rate of the petroleum hydrocarbon from well 199-N-18 and to assess remediation effectiveness.

  Monitoring well 199-N-96A, located downgradient from well 199-N-18, was characterized by 0.06 mg/L of TPH-diesel range in September 2003. This is a decrease from 1.5 mg/L in September 2002.

Appendix E presents a historical summary of contaminant and co-contaminant monitoring results.

4.4 100-NR-2 CONCEPTUAL MODEL UPDATE

The conceptual model for strontium-90 contamination at the 100-N Area has been discussed in detail in DOE-RL (1996a). Groundwater chemistry data, water-level data, and operational information gathered since 1995 continue to support the original conceptual model. This update will briefly describe the 1995 conceptual model and provide information about source removal since then.

The main sources of strontium-90 contamination are the 1301-N LWDF (also known as the 116-N-1 Facility) and the 1325-N LWDF (also known as the 116-N-3 Facility). The 1301-N Facility operated from 1964 to September 1985. The 1325-N Facility operated from 1983 to

Smart Sponge™ is a trademark of AbTech Industries, Scottsdale, Arizona.

1991. These facilities received liquid wastes from N Reactor that contained strontium-90, cobalt-60, cesium-137, plutonium, and tritium. Tritium was transported through the soil column with the liquid wastes, reaching groundwater and then moving with the groundwater. Cesium-137, cobalt-60, and plutonium were concentrated in the upper portion of the soil column beneath the LWDFs. Strontium-90 was spread throughout the soil column and into the upper aquifer.

The upper aquifer in the 100-N Area is contained in the Ringold Unit E facies of the Ringold Formation. The base of the upper aquifer is the Ringold Upper Mud Unit. The Ringold Unit E sediments at the 100-N Area are composed of sandy gravel to sandy silt. Strontium-90 is adsorbed onto the aquifer solids and is in equilibrium with dissolved-phase strontium-90. Dissolved-phase strontium-90 removed by pump-and-treat operations will come back into equilibrium with the adsorbed phase when extraction ceases. It should also be noted that adsorbed strontium-90 on aquifer solids from past discharges occurs near the shoreline, based on core samples from well 199-N-95A (DOE-RL 1995).

Dissolved-phase strontium-90 likely extends into the Columbia River riverbed to some extent based on the concentration isopleths shown in Figure 4-6. This source is beyond the influence of the pump-and-treat capture zone. However, based on sediment core profiles from near the shoreline and near the 1301-N Trench, the expected concentrations of adsorbed strontium-90 in the riverbed should be an order of magnitude lower than in the more central portion of the capture zone in the vicinity of the 1301-N Trench. Additional details regarding the adsorption-desorption process can be found in DOE-RL (1996a).

The January 1995 strontium-90 inventory for the 1301-N and 1325-N LWDF soil column and underlying saturated zone was 1,866 Ci. In this total, 88 Ci were estimated adsorbed to soil particles in the saturated zone and 0.8 Ci were dissolved in groundwater (DOE-RL 1996a). The remaining inventory was assumed to be absorbed to soil particles in the vadose zone beneath the LWDFs.

The total strontium-90 inventory decayed to 1,502.5 Ci at the end of CY03, not including the strontium-90 removed during source area excavation. This calculation was based on a strontium-90 half-life of 28.8 years. During the 9-year period from January 1995 to December 2003, the strontium-90 inventory was reduced 363.5 Ci by natural decay. The 100-NR-2 pump-and-treat system, operating from September 1995 through December 2003, removed 1.48 Ci of dissolved strontium-90 from the saturated zone. Natural decay accounted for 16.6 Ci of strontium-90 during the same time. By way of comparison, approximately 7 Ci of strontium-90 passed through the Hanford Reach in 2003 due to washout of global fallout in the upper Columbia River drainage basin. The total estimated amount of strontium-90 released to the river during reactor operations was 46 Ci. Present-day annual flux to the river has been computed to be on the order of 0.14 to 0.19 Ci/yr (DOE 2001).

Figure 4-8 presents a historical comparison of the 1995 strontium-90 plume distribution in the 100-N Area based on sample results from 1994-1995 in approximately 30 wells (before the October 1995 startup of pump-and-treat operations) and the September 2003 strontium-90 plume distribution. The difference between the two distributions is largely due to the number of data points used in contouring the plume.

4.5 QUALITY CONTROL

The data used for QC included offsite laboratory testing for total chromium, manganese, strontium-90, tritium, sulfate, and nitrate.

The highlights of QC data for CY03 100-N Area sampling are summarized in the table below. Additional tables listing complete QC results are presented in Appendix F. All sample pairs are replicates, analyzed by offsite laboratories.

Analyte	Number of Pairs	Number of Pairs <20% RPD	Percent <20% RPD
Total chromium	3	NA	NA
Manganese	3	3	100%
Strontium-90	3	3	100%
Sulfate	3	3	100%
Tritium	3	3	100%
Nitrate	3	3	100%

NA = RPD evaluation cannot be performed.

There are no functional guidelines for offsite laboratory replicate results, but the results correlated well based on the percentage of RPD <20%. A RPD calculation could not be performed on samples analyzed for total chromium because results were reported at the contract-required detection limit.

4.6 CONCLUSIONS

- ***RAO #1: Protect the Columbia River from adverse impacts from the 100-NR-2 groundwater so designated beneficial uses of the Columbia River are maintained. Protect associated potential human and ecological receptors using the river from exposure to radiological and nonradiological contaminants present in the unconfined aquifer. Protect the unconfined aquifer by implementing remedial actions that reduce concentrations of radioactive and nonradioactive contaminants present in the unconfined aquifer.***

  Results:

  - Pump-and-treat operations continue to reduce the hydraulic gradient between the Columbia River and the extraction wells. This activity is assumed to decrease the volume of inland strontium-90 contaminated water entering the Columbia River.
  - The capture area of the extraction as configured in the numerical modeling nearly matches the area predicted in DOE-RL (1996a). The pump-and-treat system is reducing net flux by approximately 96% based on a comparison of measured data and previous modeling results.
  - The pump-and-treat system has removed minimal dissolved strontium-90 from the aquifer (1.48 Ci since startup). Natural decay and excavation of near-surface sources have been much more effective in removing strontium-90 and other radiological inventory than pump-and-treat operations.

- Cost and performance results for operation of the 100-NR-2 pump-and-treat system over the last 8 years were used to estimate the current and long-term cost effectiveness of the system for reducing the concentrations and/or amount of strontium-90 in the unconfined aquifer. The lifecycle cost effectiveness ($M/Ci) of the 100-NR-2 pump-and-treat system for reducing strontium-90 in the unconfined aquifer are presented in the table below:

Year	Years from 2003	Annual Removal Rate[a] (Ci/yr)	Annual Cost[b] ($*1,000)	Esc. Factor[c]	Escalated Cost[d] ($*1,000)	Cum. Curies Removed (Ci)	Cum. Cost ($*M)	Lifecycle Cost[e] ($M/Ci)
2003	0	0.18	834.3	1	834.3	1.48	12.1	8.2
2013	10	0.141	1,092.8	1.27758	1,396.2	3.057	24.6	8.1
2028	25	0.098	1,092.8	1.82342	1,992.7	4.804	50.1	10.4
2053	50	0.053	1,092.8	3.29903	3,605.3	6.607	118.9	18.0
2103	100	0.016	1,092.8	10.79901	11,801.7	8.114	468.6	57.8

[a] The removal rate at time "t" is A_t (Ci/yr) = A_0*exp[(-0.693/28.3yr)*t], where A_0 is the initial activity (0.18 Ci/yr for 2003) and t is the number of years from 2003. It was assumed that the amount of strontium-90 removed was a constant and declined only by radioactive decay.

[b] The actual cost incurred was used for 2003. For 2004 and beyond, an average cost (excluding design and capital construction costs) was used based on actual costs incurred from 1996 through 2003, as shown in Figure 5-3.

[c] The escalation factor for inflation is 1.027 for 2004 and 2005, 1.026 for 2006, and 1.024 thereafter.

[d] Annual cost times the escalation factor.

[e] Lifecycle cost [effectiveness] = cumulative cost/cumulative curies removed.

As shown in the table above, the lifecycle cost since start of operations in 1996 is $12,100,000, and the corresponding lifecycle cost effectiveness for removal of 1.48 Ci since start of operations is $8,200,000/Ci. The cost per curie removed projected into the future allowed for inflation, maintenance, and repair/replacement of the system (approximately 25% of annual operating cost) and a declining amount of strontium-90 due to radioactive decay. These projections show a dramatic increase in cost per curie over time to nearly $60,000,000/Ci in 2103. The current estimated reduction of strontium-90 in the unconfined aquifer by radioactive decay alone is approximately 10 times greater (approximately 2 Ci/yr) than the 0.18 Ci/yr removed by the pump-and-treat system in 2003.

It is evident from the above information that the pump-and-treat system is far less efficient than radioactive decay alone in reducing the amount of strontium-90 in the unconfined aquifer. Continuing to operate the pump-and-treat system in the future will cost an average of approximately $1 million/yr (in 2003 dollars), but will increase the amount of strontium-90 removed from the aquifer by only about 10% above the amount removed by radioactive decay. It is concluded that a more cost-effective approach is needed to accomplish the objective of this RAO.

- ***RAO #2: Obtain information to evaluate technologies for strontium-90 removal and evaluate ecological receptor impacts from contaminated groundwater (by October 2004).***

  Results:

  - A workshop was held in Richland, Washington, on August 11 and 12, 2003, in order (1) to solicit tribal and stakeholder input on appropriate endpoints and measurements to assess impacts on aquatic and riparian receptors, and (2) to review potential alternative treatment technologies to minimize the impact of the 100-NR-2 plume on the Columbia River.
  - Key decision-maker interviews were conducted for the data quality objectives (DQOs) to define additional data needs for evaluation of ecological receptor impacts from groundwater. Because of inadequate Tribal representation at the August workshop, individual interviews with Tribal representatives were scheduled for early to mid-2004. Also, data needs for the River Corridor Baseline Risk Assessment (RCBRA) will be coordinated with this effort during 2004.
  - A literature review of existing aquatic and riparian data for the 100-N Area shoreline was completed as part of the ecological receptor impact DQO effort (PNNL 2003a, http://www.bhi-erc.com/Projects/risk/risk_library.htm). This document will be used during the DQO process to define additional eco-receptor data needs. The outcome of the DQO process and associated sampling and the final report will be used to help define the extent of additional treatment needed to minimize the impact of the 100-NR-2 plume on shoreline aquatic and riparian zone.
  - Based on workshop presentations and discussion of treatment options suitable to address strontium-90 at the 100-N Area, two approaches were selected for further evaluation:
    - In situ formation of apatite for passive sequestration of strontium-90
    - Phytoremediation using coyote willows (*Salix exigua*).
  - Test plans and some preliminary laboratory scoping experiments were conducted in late 2003. Laboratory and greenhouse studies to demonstrate proof-of-principle will be conducted in 2004.

- ***RAO #3: Prevent destruction of sensitive wildlife habitat. Minimize disruption of cultural resources and wildlife habitat in general and prevent adverse impacts to cultural resources and threatened or endangered species.***

  Results: The interim remedial action ROD establishes a variety of institutional controls that must be implemented and maintained throughout the interim action period. These provisions include some of the following:

  - Access control and visitor escorting requirements
  - Signage providing visual identification and warning of hazardous or sensitive areas (new signs were placed along the river and at major road entrances at each reactor area)
  - Excavation permit process to control all intrusive work (e.g., well drilling and soil excavation)

– Regulatory agency notification of any trespassing incidents.

The effectiveness of institutional controls established in the interim action ROD for 100-NR-2 (EPA et al. 1999) was evaluated and summarized for implementation and effectiveness in 2003. The *2003 Sitewide Institutional Control Annual Assessment Report for the Hanford CERCLA Response Actions* (DOE-RL 2003) presents the results for the current review. In summary, the report found that institutional controls were maintained to prevent public access as required.

4.7 RECOMMENDATIONS

Strontium-90 path forward:

As previously noted, the high cost per curie removed and the limited efficacy of the pump-and-treat system to reduce strontium-90 concentrations in the unconfined aquifer over the past 8 years demonstrates the need for alternative measures. Key elements of a recommended path forward to meet this goal are as follows:

- Continue laboratory and field testing of alternatives to using pump-and-treat (e.g., in situ formation of apatite and phytoremediation) for reducing strontium-90 released to the river.
- Terminate the treatment portion of the pump-and-treat operation while alternatives are evaluated. Because the removal rate (<0.2 Ci/yr) of strontium-90 by the treatment plant is small in relation to radioactive decay of the inventory stored on aquifer sediments and the overlying vadose zone, there is little to be gained by removing strontium-90 from the extracted groundwater. The reverse gradient created by the extraction wells, however, reduces the flux of contaminated groundwater to the river. By continuing only the extraction and reinjection portion of the existing pump-and-treat operation, the hydraulic barrier will be maintained and operating costs will be minimized. The cost savings realized can be used to accelerate evaluation of the alternative treatment options, thus moving toward a final remedy at an earlier date.
- Extend the time period for completion of the aquatic and riparian eco-receptor evaluation to October 2005 to allow more than one seasonal sampling event and to accommodate any special sampling needs for the RCBRA. In the current baseline plan, the October 2004 due date for the final report, as originally specified in the ROD, would allow only one seasonal sampling event (in the spring of 2004). The change to an October 2005 due date for the final report will allow additional seasonal sampling and closer integration with the larger scope of the RCBRA. Accordingly, the extended schedule will allow better alignment between the DQO process for the RCBRA and the 100-NR-2 aquatic/riparian eco-receptor DQO and sampling and analysis plan. This coordination is responsive to the Natural Resource Trustees and other interested parties who have requested a more holistic study of the river. Extending the 100-NR-2 eco-receptor assessment schedule will allow the needs of both assessments to be addressed at the same time and thus avoid duplication of efforts. Also, the product of the RCBRA and the 100-NR-2 eco-receptor evaluation will help determine the extent of treatment needed for human heath and ecosystem protection, further emphasizing the need for close coordination of the above activities.

Other 100-NR-2 contaminants:

- Determine the effectiveness of the passive removal method to treat free-product diesel fuel in selected wells near the past bunker oil/diesel spill sites, and revisit other wells in the plume area for signs of biodegradation (natural attenuation). Document evidence of reported oil slicks or films along the shoreline near the 100-N Area.
- Conduct a camera survey in well 199-N-80 to determine if the chromium concentrations in the well are a result of deteriorating well casing (particulates) or if all of the chromium is dissolved in the groundwater.

Figure 4-1. 100-N Area Operable Unit Location.

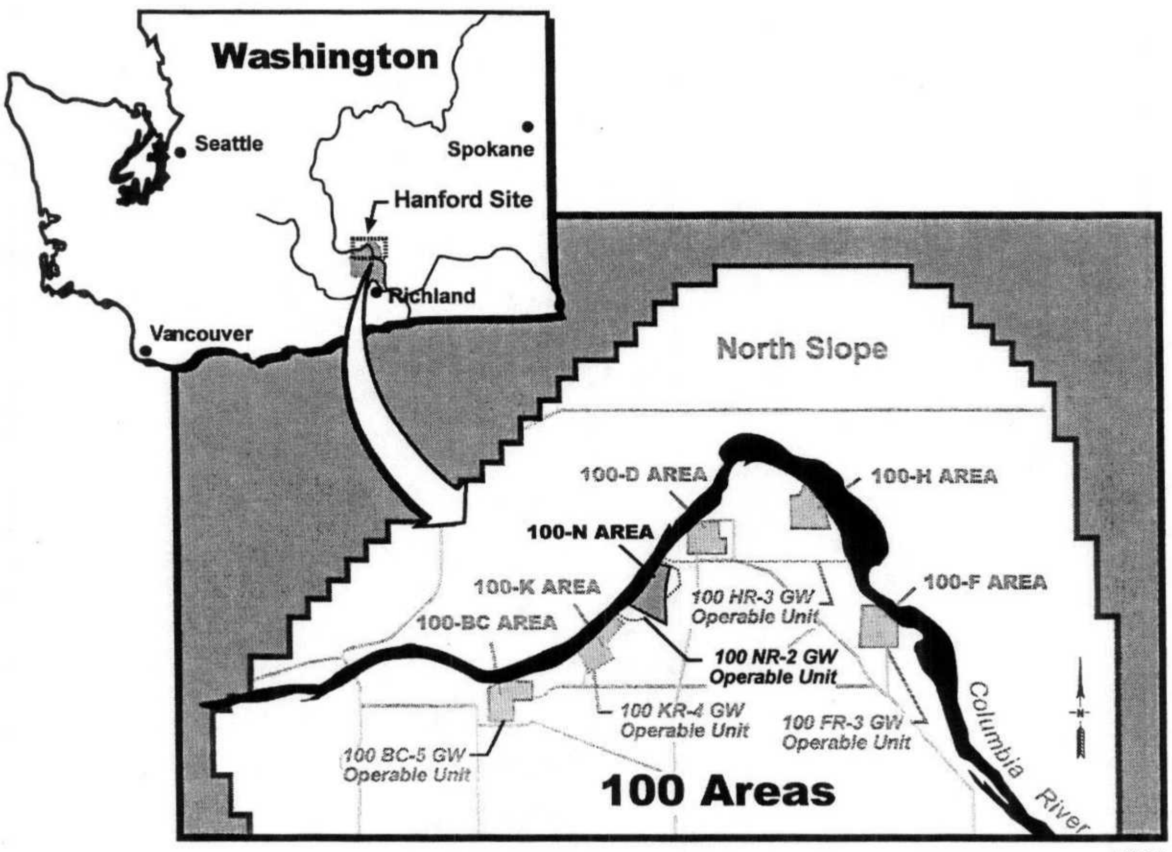


Figure 4-2. 100-NR-2 Operable Unit Wells and Seeps.

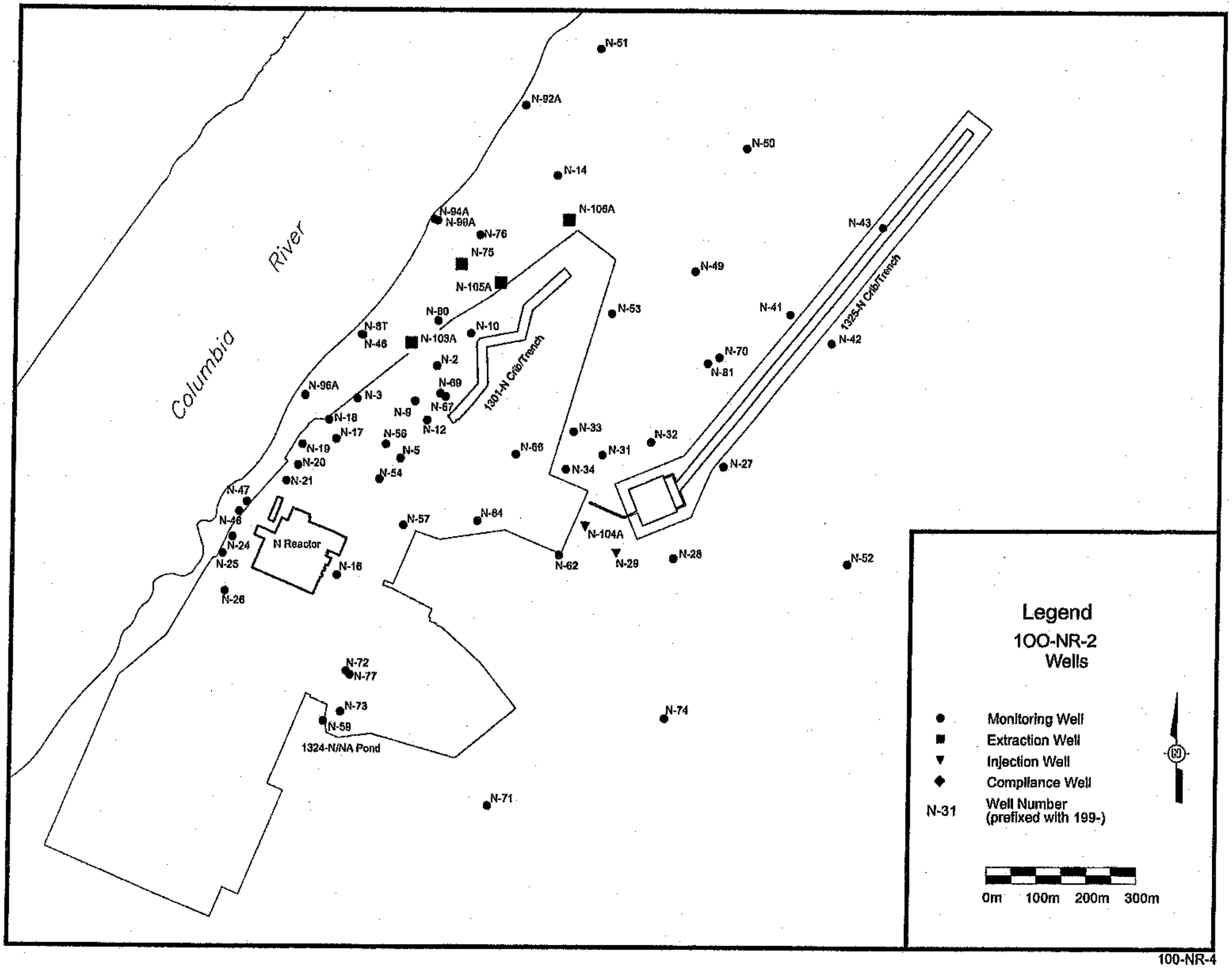


Figure 4-3. 100-NR-2 Pump-and-Treat System Schematic.

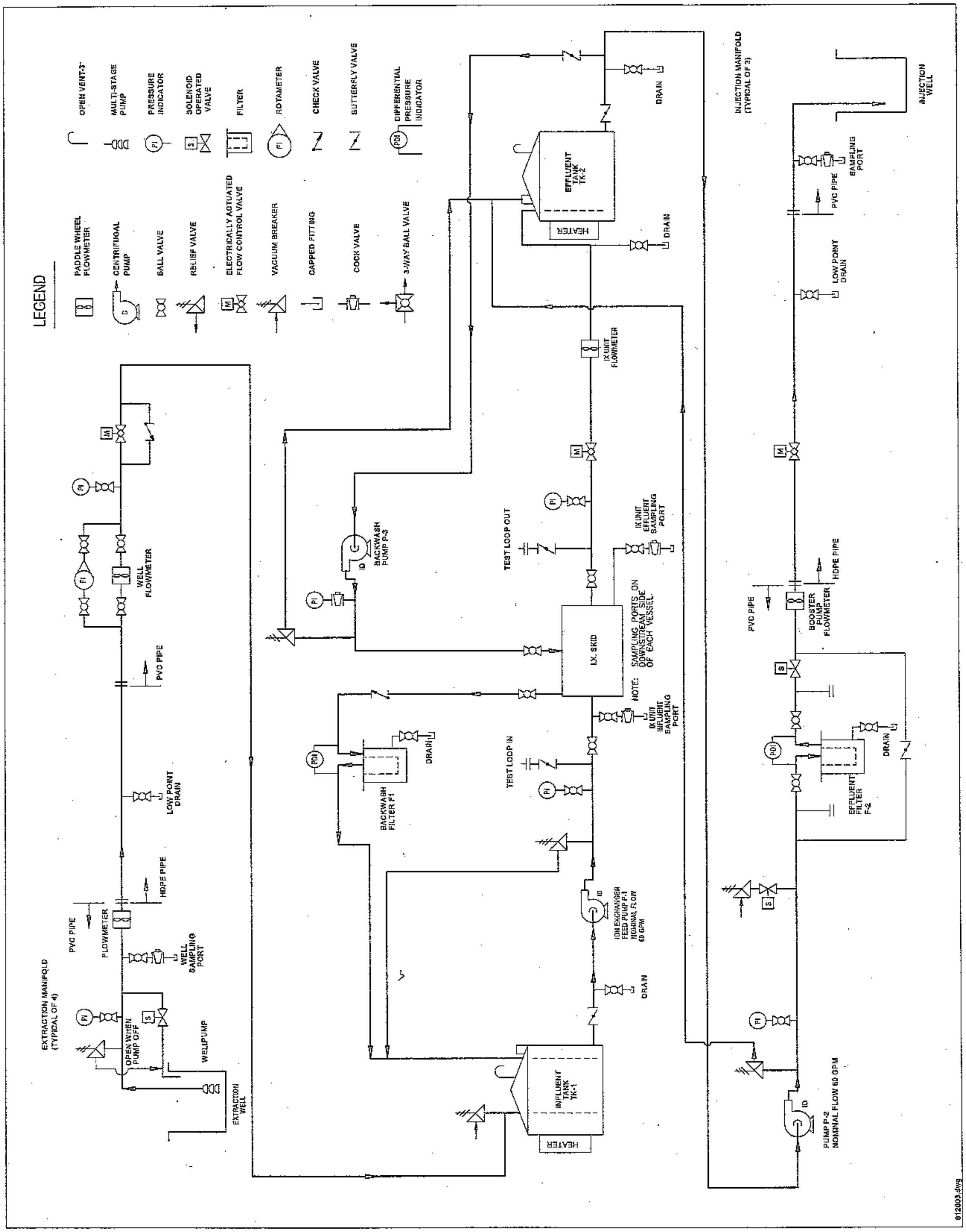
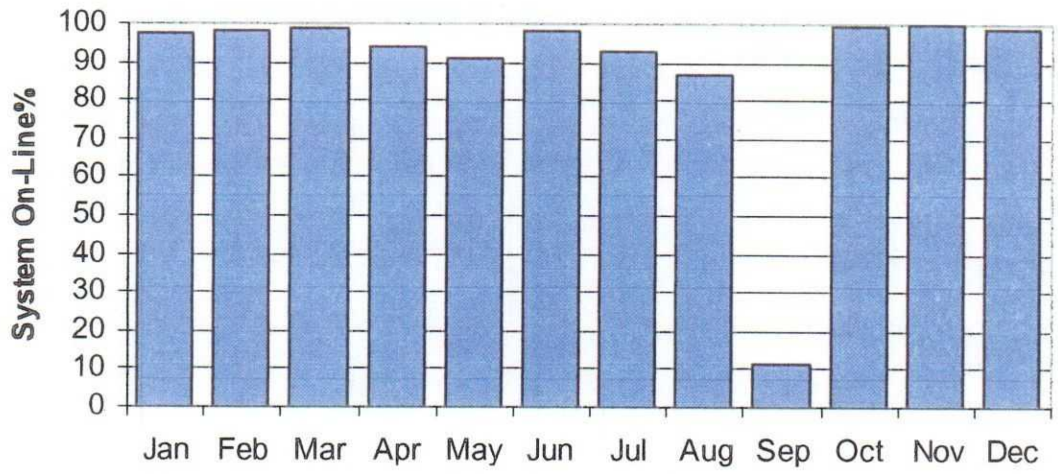


Figure 4-4. 100-NR-2 System Availability and On-Line Percentages for Calendar Year 2003.



January 9: Clino change for 6.5 hours.

January 24: Failure of extraction well pump 199-N-103. System down for a total of 12 hours.

February 5: Clino change for 13 hours.

March 5: Clino change for 9 hours.

April 2: Clino change for 25 hours.

April 30: Clino change for 25 hours.

May 28: Clino change for 54.5 hours.

June 26: Clino change for 7 hours.

July 6 to 8: System down periodically during the interval for 12 hours due to power outages.

July 28 to 29: Clino change out for 21 hours.

August 14: System shut down due to 100 Area-wide schedule power outage for 84 hours.

August 18: System shut down due to 100 Area-wide schedule power outage for 7 hours.

September 2: System shut down for 470.5 hours for scheduled maintenance.

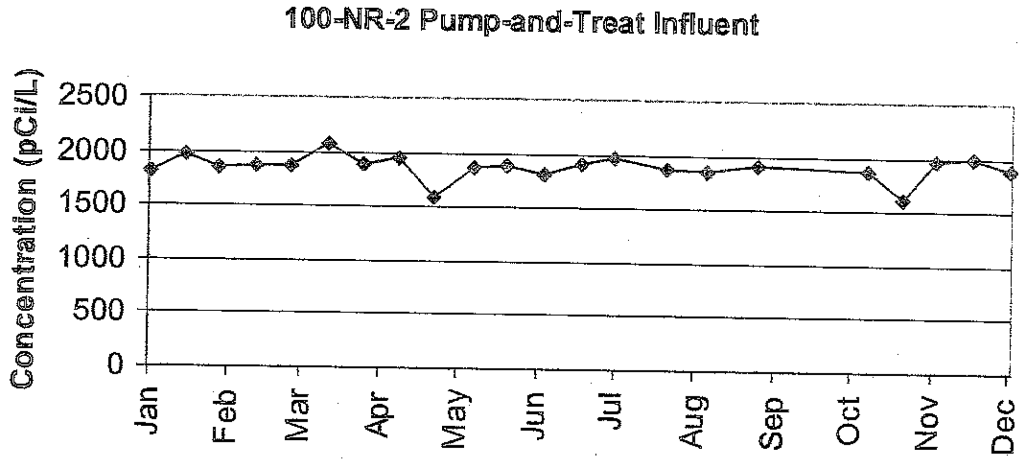
September 22: System startup delayed 144 hours due to lock-and-tag issue.

September 25: Clino change for 14 hours.

October 29: Clino change for 8 hours.

November 25: Clino change for 29.5 hours.

Figure 4-5. 100-NR-2 Pump-and-Treat Trends of Influent and Effluent Strontium-90 Concentration for Calendar Year 2003.



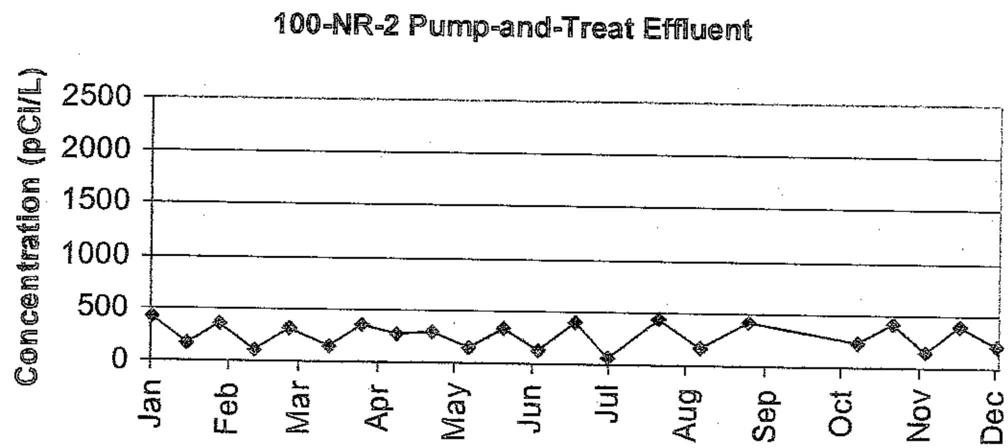


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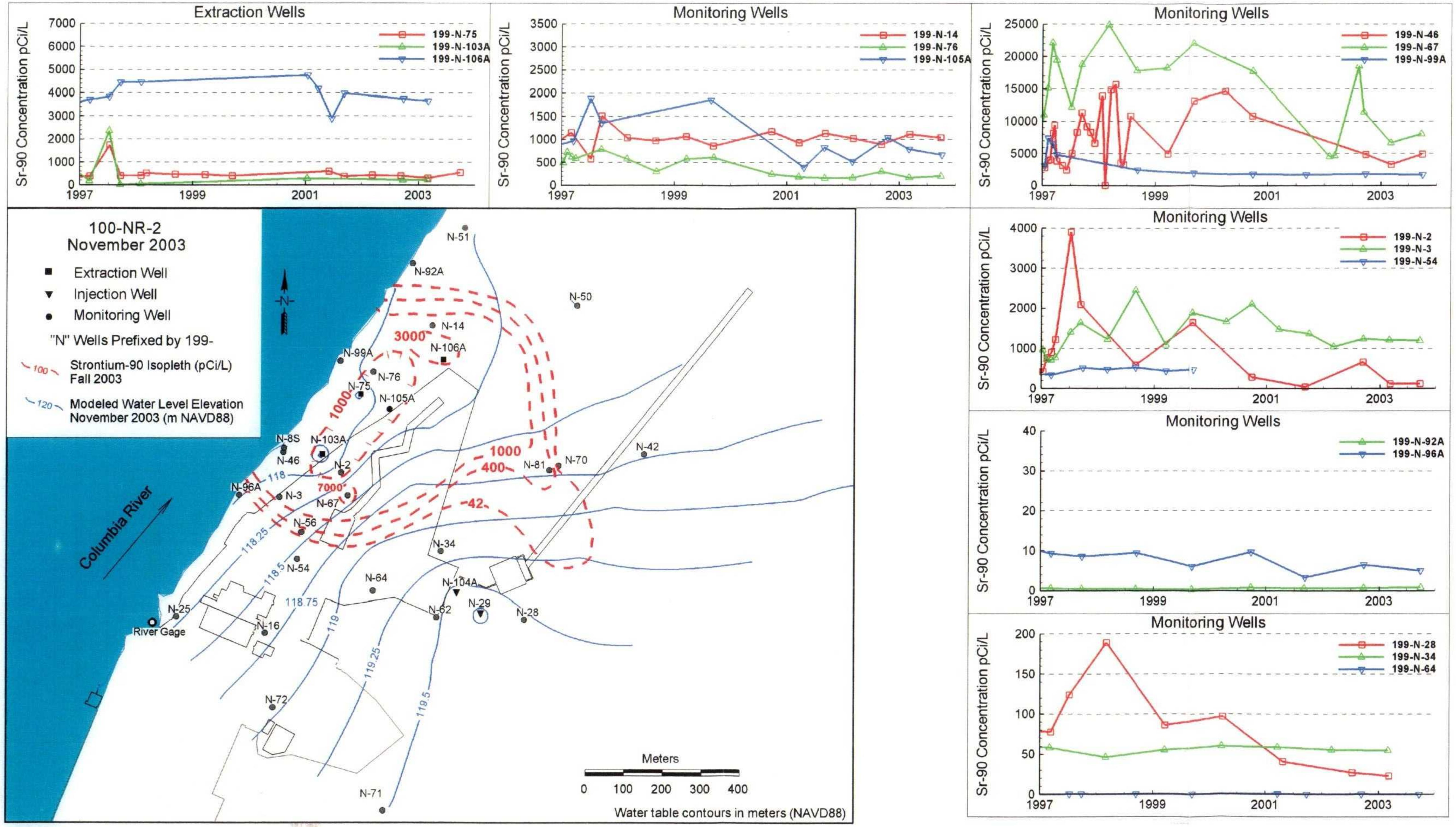
Figure 4-6. 100-NR-2 Strontium-90 Plume, September 2003.



*Well 199-N-105A is used as a monitoring well and backup extraction well.

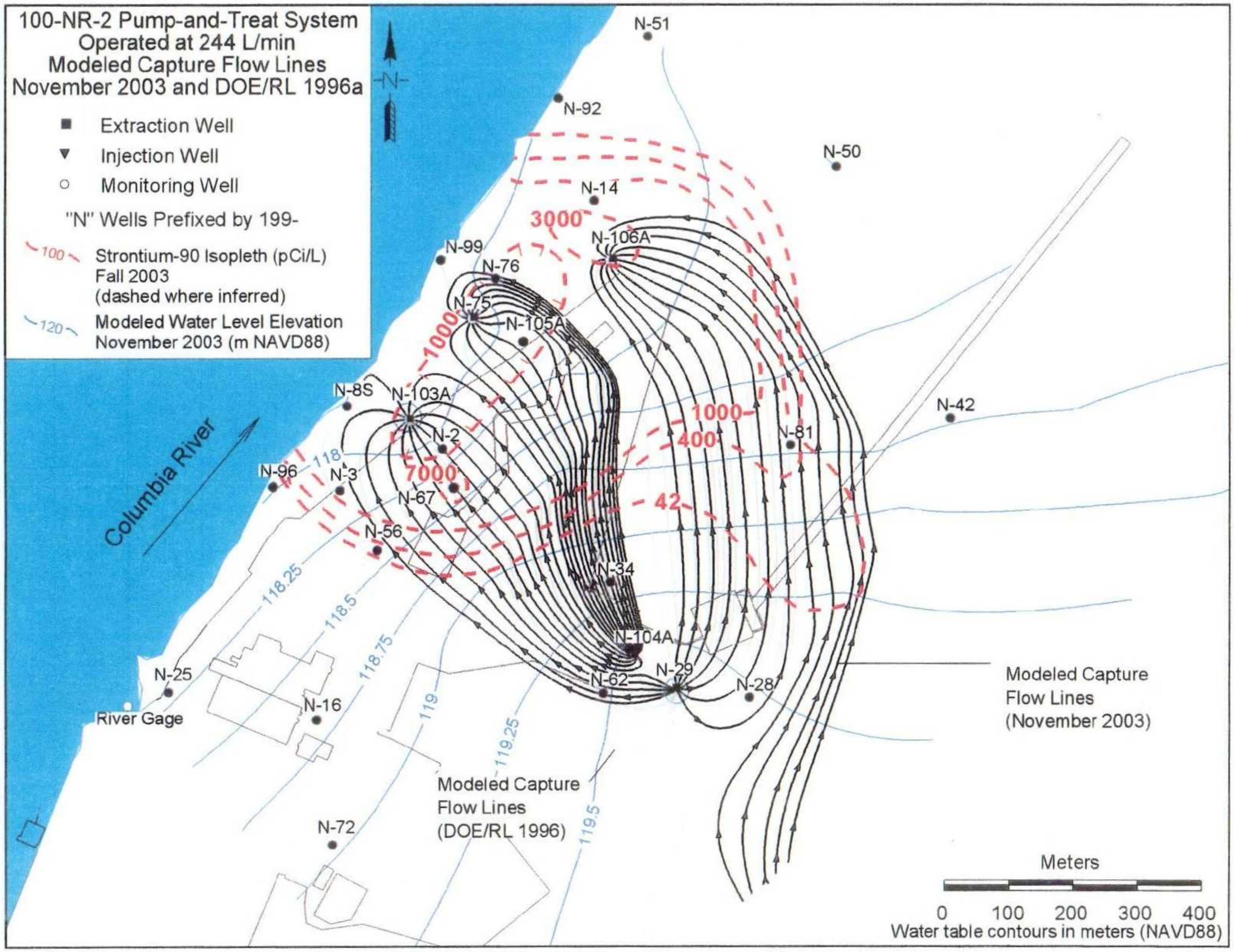


Figure 4-7. Comparison of November 2003 Modeled Capture Flow Lines (Operated at 227 L/m) to Predicted Capture Flow Lines (DOE-RL 1996a).

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Figure 4-8. 100-N Operable Unit Chromium Plume Map, 1997 and 2003.

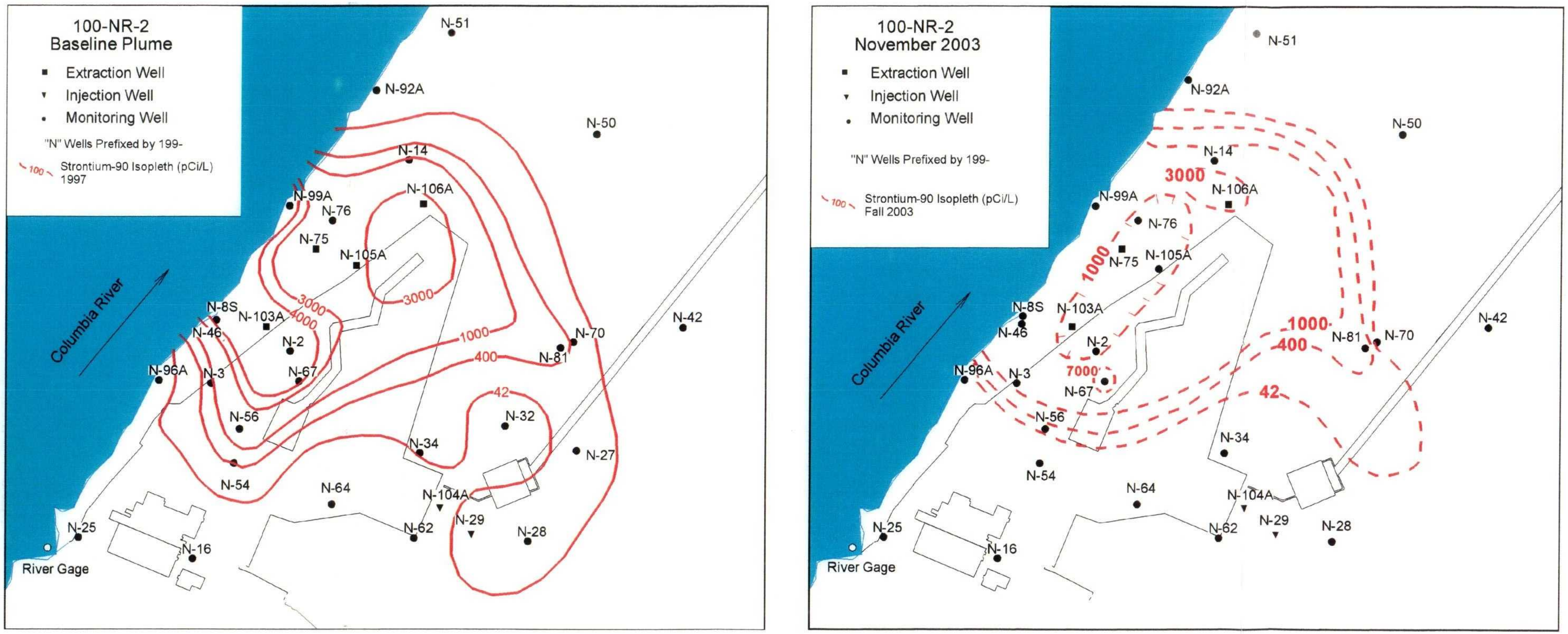

Table 4-1. 100-NR-2 Operable Unit Water-Level Data.

Well	Extraction Rate (L/min)	Injection Rate (L/min)	Measured Elevation, Nov. 2003 (m NAVD88[1])	Modeled Elevation, Nov. 2003 (m NAVD88[1])
199-N-75	40	—	118.48	117.44
199-N-103A	60	—	140.77	117.10
199-N-106A	144	—	122.21	117.98
199-N-105A	0	—	111.66	118.10
199-N-29	—	159	120.61	120.18
199-N-104A	—	85	126.06	119.79
199-N-2	—	—	118.08	118.12
199-N-3	—	—	118.21	118.11
199-N-8S	—	—	117.93	117.92
199-N-14	—	—	117.94	118.10
199-N-16	—	—	118.51	118.69
199-N-50	—	—	118.16	118.25
199-N-76	—	—	117.95	118.02
199-N-92	—	—	118.18	118.01
199-N-99	—	—	118.03	118.00
199-N-34	—	—	119.08	119.16
199-N-72	—	—	118.78	118.97

[a] NAVD88, 1983, *North American Vertical Datum of 1988*, National Geodetic Survey, Federal Geodetic Control Committee, Silver Springs, Maryland.

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5.0 PUMP-AND-TREAT SYSTEM COST DATA

Actual costs for the 100-HR-3, 100-KR-4, and 100-NR-2 pump-and-treat systems were recorded in FH's Hanford Data Integrator. The data are used to determine the actual capital and expense costs associated with a specific activity during the FY. Specific activities are briefly described below:

- Capital design: Includes design activities to construct the pump-and-treat systems and designs for major system upgrades and modifications.
- Capital construction: Includes oversight labor, material, and subcontractor fees for capital equipment, initial construction, construction of new wells, redevelopment of existing wells, and modifications to the pump-and-treat system.
- Project support: Includes project coordination-related activities and technical consultation as required during the course of the facility design, construction, acceptance testing, and operation.
- Operations and maintenance: Represents facility supplies, labor, and craft supervision costs associated with operating the facility. It also includes costs associated with routine field screening and engineering support as required during the course of pump-and-treat operation and periodic maintenance.
- Performance monitoring: Includes system and groundwater sampling and sample analysis as required in accordance with the 100-HR-3 and 100-KR-4 interim action work plan (DOE-RL 1996b).
- Waste management: Includes the cost for the management of spent resin at 100-HR-3 and 100-KR-4 and spent clinoptilolite in accordance with the applicable laws for suspect hazardous, toxic, and regulated wastes. It includes waste designation sampling and analysis. Also included are resin regeneration costs and new resin purchase.

Costs are burdened and are based on actual operating costs incurred during FY03 and represent a comparison between FY02 and FY03 costs.

5.1 100-HR-3 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-HR-3 pump-and-treat system is presented in Figure 5-1. Total construction and operation costs for FY03 are lower when compared to FY02. Cost reductions are attributed to no capital construction costs and lower project support and operations costs. These items were higher in FY02 due to system enhancements and improvements conducted for the CERCLA 5-year review. As shown in Figure 5-1, the total costs by percent of the total indicate that the majority of costs, in decreasing order of magnitude, are charged to waste management (44%), operations and maintenance (37%), project support (11%), and performance monitoring (8%). Based on the FY03 costs ($2,012,000) and yearly production rate of 416.5 million L and 42.9 kg of hexavalent chromium removed, the annual treatment costs equate to $0.005/L or $47/g of hexavalent chromium removed. The treatment costs are lower in comparison to FY02 and CY03 costs.

5.2 100-KR-4 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-KR-4 pump-and-treat system is shown in Figure 5-2. Compared to FY02, total construction and operations costs are lower in FY03. Cost reductions are attributed to significantly lower capital construction, project support, and operations costs. These costs were higher in FY02 due to system enhancements and improvements conducted for the CERCLA 5-year review. As shown in Figure 5-2, the total costs by percent of the total indicate that costs are charged, in decreasing order of magnitude, to operations and maintenance (36%), waste management (32%), treatment system capital construction (18%), project support (8%), and performance monitoring (6%). Based on the FY03 costs ($2,215,800) and yearly production rate of 517.6 million L and 36.6 kg of hexavalent chromium removed, the annual treatment costs equate to $0.004/L or $60/g of hexavalent chromium removed. The treatment costs are slightly lower for FY03 when compared to FY02 costs.

5.3 100-NR-2 PUMP-AND-TREAT SYSTEM COSTS

The cost breakdown for the 100-NR-2 pump-and-treat system is presented in Figure 5-3. Compared to FY02, total construction and operation costs are significantly lower in FY03. Cost reductions are attributed to lower project support and waste management costs. As shown in Figure 5-3, the total costs by percent of the total indicate that costs are charged, in decreasing order of magnitude, to operations and maintenance (73%), project support (16%), performance monitoring (6%), and waste management (5%). Based on the FY03 costs ($834,300) and yearly production rate of 114.1 million L and 0.18 Ci of strontium-90 removed, the annual treatment costs equate to $0.007/L or $4,635,000/Ci of strontium-90 removed. The treatment costs in are lower in FY03 when compared to FY02 costs.

Figure 5-1. 100-HR-3 Pump-and-Treat System Costs. (2 sheets)

Cost Breakdown for 100-HR-3 Pump-and-Treat Construction and Operations

Description	Actual Costs (Dollars X 1,000)							
	1996	1997	1998	1999	2000	2001[a]	2002[v]	2003
Design	2,040.0	--	--	--	--	97.7	15.4	8.1
Treatment system capital construction	164.0	--	--	--	57.7	(36.1)	750.3	--
Project support	--	741.0	264.9	265.3	276.7	225.8	309.3	229.8
Operations and maintenance	948.0	3,437.0	1,533.3	1,650.8	799.1	739.2	816.6	733.7
Performance monitoring	--	259.0	0.4	--	173.7	219.9	120	163.2
Waste management	--	--	--	--	895.3	424.9	720.1	877.2
Totals	**$3,152.0**	**$4,437.0**	**$1,798.6**	**$1,916.1**	**$2,202.5**	**$1,671.4**	**$2,731.7**	**$2,012.0**

\- = not available.

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc..

100-HR-3 Pump-and-Treat System Fiscal Year 2003 Cost Breakdown (by Percentage)

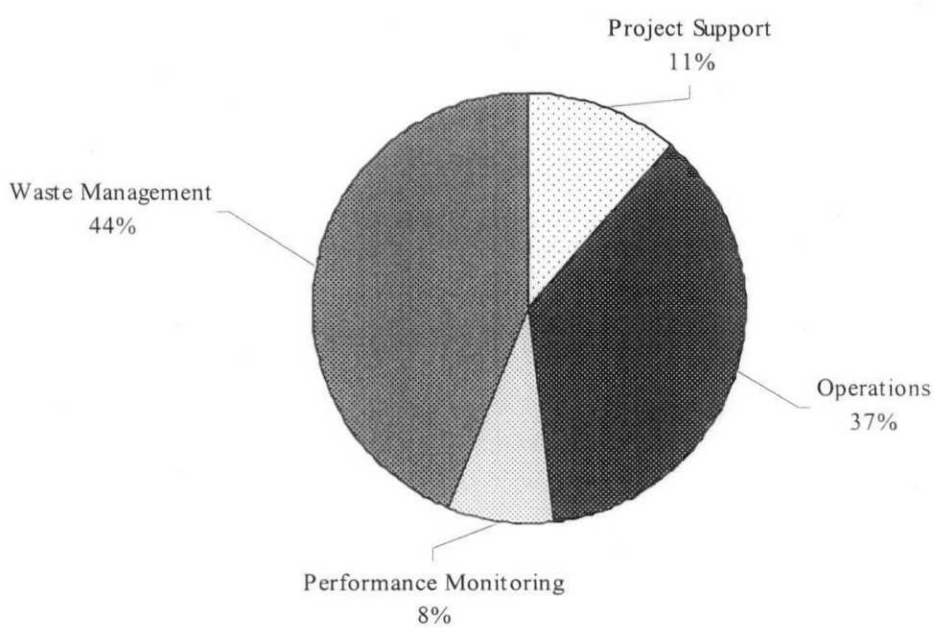


Figure 5-1. 100-HR-3 Pump-and-Treat System Costs. (2 sheets)

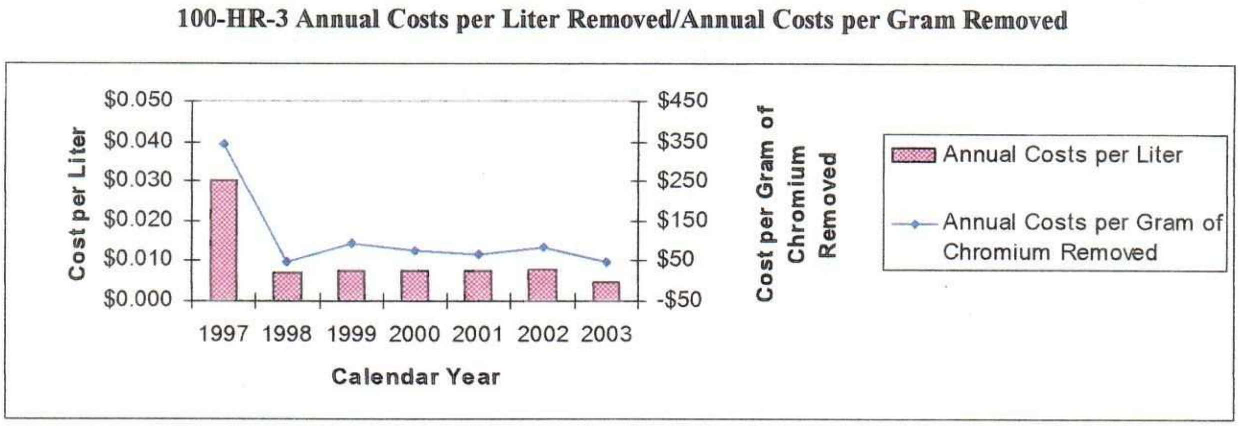


Figure 5-2. 100-KR-4 Pump-and Treat System Costs. (2 sheets)

Cost Breakdown for 100-KR-4 Pump-and-Treat Construction and Operations

Description	Actual Costs(Dollars X 1,000)							
	1996	1997	1998	1999	2000	2001[a]	2002[b]	2003
Design	1,060.0	163.0	85.4	0.2	--	96.5	55.2	70.8
Treatment system capital construction	81.0	--	--	--	109.1	(0.1)	860.1	379.9
Project support	--	327.0	208.4	157.2	143.0	188.2	257.8	171.0
Operations and maintenance	869.0	2,525.0	1,028.9	717.4	538.0	578.6	771.9	789.7
Performance monitoring	--	382.0	1.4	--	111.2	122.6	124.6	119.7
Waste management	--	--	--	--	481.8	367.5	343.3	684.7
Totals	**2,010.0**	**$3,397.0**	**$1,324.1**	**$874.8**	**$1,383.1**	**$1,353.3**	**$2,412.9**	**$2,215.8**

- = not available.

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

100-KR-4 Pump-and-Treat System Fiscal Year 2003 Cost Breakdown (by Percentage)

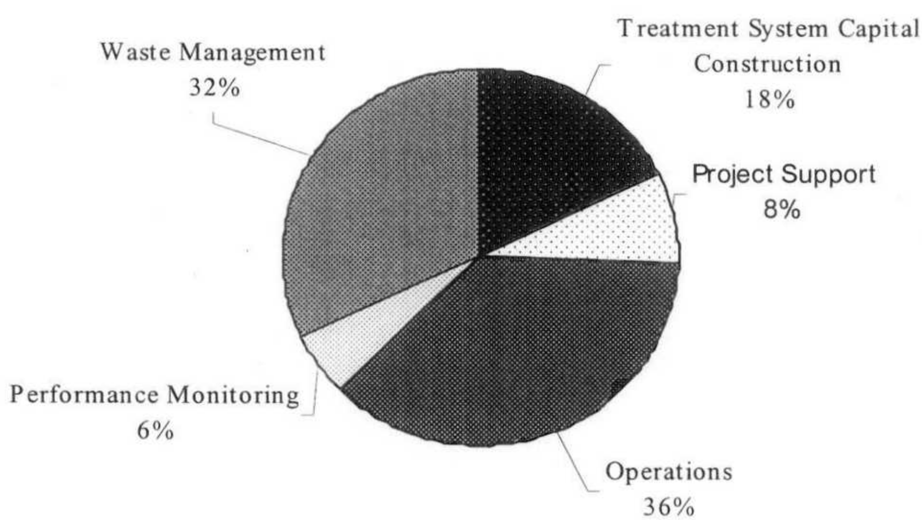


Figure 5-2. 100-KR-4 Pump-and Treat System Costs. (2 sheets)

100-KR-4 Annual Costs per Liter Removed/Annual Costs per Gram Removed

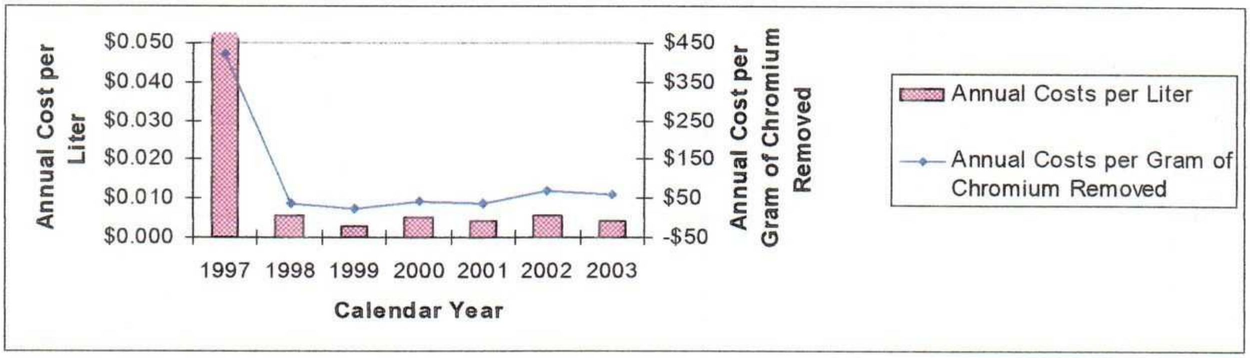


Figure 5-3. 100-NR-2 Pump-and Treat System Costs. (2 sheets)

Cost Breakdown for 100-NR-2 Pump-and-Treat Construction and Operations

Description	Actual Costs (Dollars X 1,000)							
	1996	1997	1998	1999	2000	2001[a]	2002[b]	2003
Design	2,289.4	951.8	32.6	0.2	--	--	--	
Treatment system capital construction	55.0	--	-	--	--	--	--	
Project support	--	119.4	136.0	113.1	96.3	183.5	219.4	133.0
Operations and maintenance	2,622.7	1,027.8	425.2	657.4	462.2	631.5	631.8	604.3
Performance monitoring	--	--	--	--	82.6	83.1	72.4	51.6
Waste management	--	--	--	--	131.6	112.5	100	45.4
Totals	**$4,967.1**	**$2,099.0**	**$593.8**	**770.7**	**$772.7**	**1,010.6**	**$1,023.6**	**$834.3**

- = not available.

[a] 2001 costs corrected for Project Support and Waste Management. Initial expense calculations for 2001 were not properly categorized.

[b] 2002 accrual costs corrected for appropriate split between Bechtel Hanford, Inc. and Fluor Hanford, Inc.

100-NR-2 Pump-and-Treat System Fiscal Year 2003 Cost Breakdown (by Percentage)

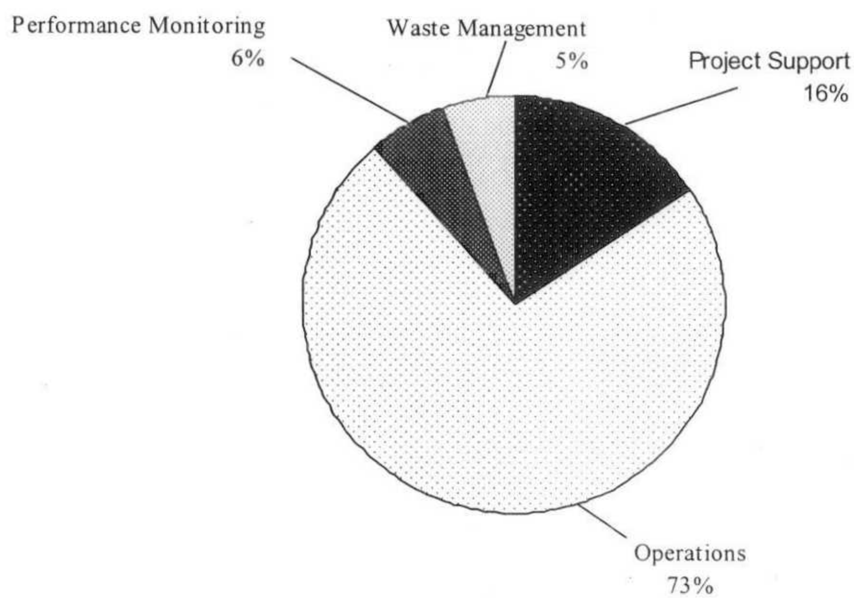
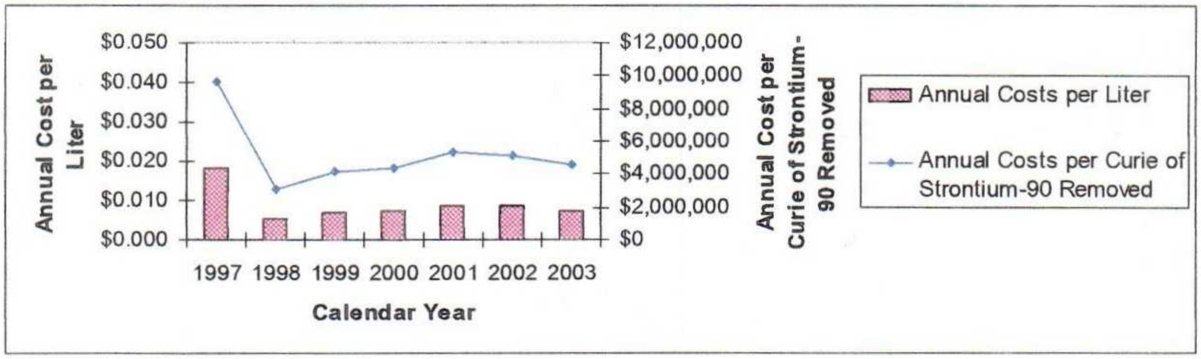


Figure 5-3. 100-NR-2 Pump-and Treat System Costs. (2 sheets)

Annual Costs per Liter Removed/Annual Costs per Curie Removed



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